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Preparation of a Stable, Dilute Solution of Phosphate Standard for Routine Work aboard the Ship

By

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(Received April 18, 1963)

Abstract: Method of preparation and storage of a stable, dilute standard solution of phosphate for a routine work aboard the observation ship is described. No change in the concentration of the solution was recognized when kept at the temperature of 30° to 40°C over 50 days. A satisfactory method of storage of stannous chloride solution used as a reducing agent is also referred to.

1. Introduction

Two series of oceano-chemical intercalibration tests were made under the request of SCOR and the auspices of UNESCO, first in Hawaii, 1961 and second in Australia, 1962. The main purpose of these meetings were to intercompare the analytical results of phosphate and dissolved oxygen in sea waters collected and analysed simultaneously among the participants of the International Indian Ocean Expedition, 1962 to 64. One month later than the second international meeting, the first internal meeting of the same kind was held on Sagami Bay aboard R.V. the "Ryofu-maru", the Japan Meteorological Agency. Twelve participants met from Japan Meteorological Agency, Japanese Hydrographic Office, Tokyo University of Fisheries, Shimonoseki College of Fisheries, Nagoya University, Kobe Marine Observatory, Maizuru Marine Observatory and Meteo-

	P $\mu\text{g-at/l}$	O ₂ ml/l
USSR	2.009 $\pm$ 0.012	3.619 $\pm$ 0.014
Australia	2.227 $\pm$ 0.014	3.670 $\pm$ 0.010
Japan	2.231 $\pm$ 0.052	3.597 $\pm$ 0.032
USA	2.023 $\pm$ 0.019	3.634 $\pm$ 0.035

rological Research Institute. Intercalibration was made on phosphate and oxygen. For indicating the general trend confirmed in the results of these intercalibrations, an example obtained in Australia, Aug. 1962 is shown above.

How the difference beyond the precision of the measurement among the participants can be explained? A decisive conclusion could not be obtained for this. But, as one of possible factors causing the difference larger than the expected from the size of precision, the error can be considered which may be introduced in making the standard solution of phosphate and/or in diluting this solution to obtain the diluted, standard solution which can be used as a direct reference in photometry. Therefore, if the stable, diluted standard solution of phosphate and etc. can be made at one place and distributed among the participants like in the case of standard sea water, the chance of introduction of the error will be diminished. In this report mention will be made only on phosphate. As well known, dilute solution of phosphate like sea water (ordinarily less than $3.0 \mu\text{g-at/l}$) is liable to change its concentration mainly due to biochemical reaction during storage. So, usually it can not be stored without any change in concentration. But, as this time the stable, dilute solution of phosphate could be obtained, the method of preparation and storage and the results of check on concentration during storage are described.

2. *Method of preparation and storage*

(1) *Preparation and storage of sodium chloride solution for blank determination*

Pure sodium chloride of 310 g is dissolved in distilled water which has been cooled to a room temperature after boiled. All utensils described hereafter are sterilized by filled up with boiling water or heated above 100°C in a hot air sterilizer. Add 500 mg of Fe in the form of ferric chloride as a scavenger and precipitate it with ammonia. Filter. Boil the filtrate for 30 minutes. Add 500 mg of Fe and precipitate again with ammonia. Heat the turbid solution nearly up to boiling. Filter. Boil the filtrate to expel ammonia. Thereafter, check pH of the solution to ascertain the complete escape of ammonia. Dilute the solution to 10 liters with boiled out distilled water. Chlorinity of this solution is about 18.8‰. Transfer it to a 10 liter glass bottle. No addition of sterilizer. Pour the solution into a 250 ml ampoule made of amber glass.

(2) *Preparation and storage of dilute, standard solution*

In one liter of distilled water while boiled is dissolved 0.40 g of KH_2PO_4

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which has been purified and dried at 110°C. The concentration of this solution is approximately 3 $\mu\text{g-at/ml}$. An appropriate amount of this solution is added to the sodium chloride solution previously mentioned to get a dilute, standard solution as a direct reference. For instance, 10 ml of the phosphate solution (3 $\mu\text{g-at/ml}$) is added to 10 l of sodium chloride solution (31 g/l). No addition of sterilizer. Pour the solution into a 250 ml ampoule made of amber glass. This time three kinds of solutions were prepared. First, no addition of phosphate salt to the sodium chloride solution. Second, about 1.5 $\mu\text{g-at/l}$ and third, about 3.0 $\mu\text{g-at/l}$ with neglect of phosphate content in the sodium chloride solution.

3. Check on stability of dilute, standard solution

A day after preparation of dilute, standard solution of phosphate, the concentration of the solution was determined by comparing it with the standard solution which was prepared on the same day as checked by dissolution of solid KH_2PO_4 into distilled water. Every about two weeks later on, the concentrations of the solutions in ampoules were checked with the standard solution freshly prepared every time. The ampoule containing phosphate solution were always

Table 1. Stability of the dilute solution of phosphate.
Date of preparation: Dec. 23, 1962

Approx. conc'n.* $\mu\text{g-at/l}$	Found on			
	Dec. 24, '62		Jan. 5, '63	
	R $\mu\text{g-at/l}$	R-R ₀	R $\mu\text{g-at/l}$	R-R ₀
0	0.22±0.03 (R ₀)	0	0.21 (R ₀)	0
1.5	1.78±0.06	1.56	—	—
3.0	3.25±0.095	3.03	3.19	2.98

Approx. conc'n.* $\mu\text{g-at/l}$	Found on			
	Jan. 26, '63		Feb. 14, '63	
	R $\mu\text{g-at/l}$	R-R ₀	R $\mu\text{g-at/l}$	R-R ₀
0	0.20 (R ₀)	0	0.20 (R ₀)	0
1.5	1.75	1.55	1.70	1.50
3.0	3.20	3.00	3.18	2.98

* Phosphate concentration in NaCl solution is neglected.

stored at 30° to 40°C. Results of check on the concentration are shown in Table 1.

In Table 1 it can be seen that the concentration of the solution in the ampoule is kept constant within the range of precision for about 50 days at 30° to 40°C. Consequently, it can be said with a fairly good reliability that a dilute, standard solution of phosphate prepared and stored in an amber glass ampoule in such a way as mentioned before is practically useful: There is no need to make a dilute solution usable as a direct reference from the phosphate standard solution every time at needs.

4. Discussion

Before arriving at this conclusion, we tried two, different methods without successes. In one trial sea water was used as a diluent after filtered with a

Table 2. Variation of concentration in two kinds of dilute, standard solution of phosphate.

I. Filtered sea water was used as a diluent.

Date of preparation: Oct. 20, 1962.

Wanted conc'n. $\mu\text{g-at/l}^*$	Found on				
	Oct. 30	Nov. 21	Dec. 12	Dec. 28	Jan. 25
	$\mu\text{g-at/l}^{**}$				
0.0	0.78	0.98	1.25	1.00	1.14
0.5	1.70	—	1.23	1.09	1.25
1.0	1.13	0.72	0.75	0.65	1.02
2.0	3.72	1.98	1.98	1.84	1.90
3.0	3.88	2.90	3.09	3.25	3.05

II. NaCl solution (31 g/l) was used as a diluent.

Date of preparation: Dec. 17, 1962.

Wanted conc'n. $\mu\text{g-at/l}^*$	Found on				
	Dec. 19	Dec. 28	Jan. 5	Jan. 25	Feb. 12
	$\mu\text{g-at/l}^{**}$				
0	0.46	0.79	0.33	0.31	0.50
1.0	1.75	0.99	1.58	1.69	1.64
2.0	2.07	2.86	2.67	2.86	1.78
3.0	4.03	3.24	3.10	4.05	3.37

* P-content in NaCl solution is neglected.

** P-content in NaCl solution is included.

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filter paper and in another sodium chloride solution was used as a diluent with once scavenging with soluble ferric salt and ammonia while boiling. Sequences of variation in concentration in these two trials are shown in Table 2.

These results being taken into account, the method described in the previous section was employed. The idea on which the method is based is as follows:

(1) Sea water is too complicated in nature to be simply purified. It seems to contain too much tenacious problems. So, sea water was replaced by sodium chloride solution.

(2) When ferric ion is added to ammoniacal solution, phosphate will precipitate if any.

(3) Filtration after making flocculent precipitate of ferric hydroxide is more effective than filtration of plain solution to capture and remove the minute suspensoid including marine biota.

(4) Sodium chloride solution might contain material which can produce phosphate after heating. It being taken into account, ferric hydroxide was first precipitated while cool.

(5) Second precipitation was made so that colloidal, ferric salt and other remainders otherwise passing through a filter might be entirely well caught.

(6) Biochemical breakdown of phosphate-inducing material will be aroused by enzymatic action even though there is no active bacterium. So, it was thought that there is no need for sterilizer to be added to the solution. And the heating was thought necessary to destroy the enzymatic action.

Addendum

It is well known that the concentration and the amount for once application of stannous chloride solution play an important role in determining concentration of phosphate photometrically. But, the concentration of a dilute, stannous solution is quite apt to change due to oxidation in contact with the air. For prevention against it, someone recommend to prepare freshly a dilute solution of stannous chloride for each batch of analysis whenever necessary, and others recommend to make the diluted reagent solution up daily and store for short periods under paraffin oil. But anyway, both are tedious and troublesome particularly on board. Then, we tried to keep the solution in contact with a small grain of tin in an ampoule. Crystals of stannous chloride ($\text{SnCl}_2 \cdot 2\text{H}_2\text{O}$, 2g) was put in 40 ml of concentrated hydrochloric acid and heated somewhat to be

dissolved. Thereafter, 160 ml of boiled-out distilled water was added. About ten ml of this solution was poured into the ampoule in which a small grain of tin was put. It was desirable that the volume of the air left over the solution in the ampoule is as small as possible.

In order to check on the probable variation in concentration of stannous solution, the extinction of the coloured solution of the reduced phosphomolybdate was compared between when the stannous solution stored in the ampoule until the time of use, and when the stannous solution freshly prepared everytime, was employed. The result was that there was no change of ampoule to ampoule in one batch of the solution prepared at the same time and no change between the freshly prepared batch and the one prepared in 1959.

Acknowledgement: This work was started by the suggestions of Prof. Y. MIYAKE and Prof. K. SUGAWARA prior to the cooperative operation in the Indian Ocean, 1962. Authors'thanks are due to both professors for their encouragement throughout this work.

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Suitability of a Recording Photometer for Photometric Work aboard the Observation Ship

By

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Abstract: The suitability of a recording photometer for the photometric work aboard the observation ship is mentioned from the view-point of phosphate determination. 1. No disturbance on photometry due to rolling and / or pitching of the ship. 2. Easy to confirm that the photometry is being done under a satisfactory condition. 3. Needless to read the absorbancy instantly at the maximal coloration of phospho-molybdate.

1. Introduction

A reliable sea-going photometer has long been desired. At the international intercalibration test meeting held aboard the Russian observation ship the "Vityaz" off Fremantle, Western Australia, a null method consisting of a single light beam, two photocells and magic eye or voltmeter as a null-point indicator was employed by Australia and USSR. While a one photocell filter photometer conjugated with a recording potentiometer* was used by a Japanese participant (one of the authors, Y. SUGIURA). At this occasion, the latter instrument could not display a complete function owing to the minor deficit as described later. Consequently, it was temporarily concluded that the latter was inferior to the former instrument.¹⁾ But afterwards, the causes to arise malfunction was confirmed and removed. It was recognized after reformation at the JDES-6 cruise that the instrument worked satisfactorily and it was, more-

* A prototype of this instrument was originally devised by Ryoji HIGANO, Hydrographic Office of Japan. The chemical working group of the National Committee of Oceanographic Research recommended that the one photocell filter photometer conjugated with a recording potentiometer should be used aboard all ships participating in the International Indian Ocean Observation.

over, more convenient for phosphate determination aboard the ship. The results obtained at that time will be mainly described below.

2. Records obtained by the recording photometer

One of the records obtained with the recording photometer at time of the intercalibration test in Australia is shown in Fig. 1. This result was obtained with a rectangular cuvette (100 mm long, open upside, 50 ml capacity). Figures allotted to seven, vertical lines in Fig. 1 indicate the percentage transmittancy. In the record, the printing of a recording pen can be seen not to run straight but to vibrate laterally.

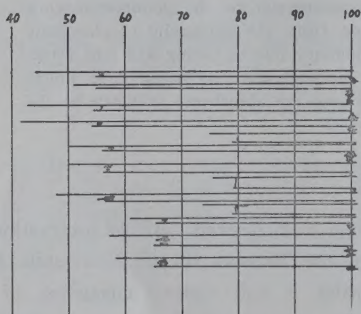


Fig. 1 Record of the recording photometer with a pair of rectangular cuvettes.

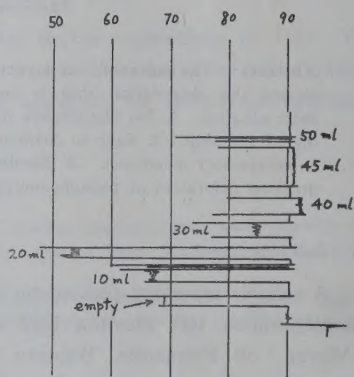


Fig. 2 Record obtained with a pair of test-tubing type cells.

Fig. 2 is the record obtained with a test-tubing type cell (40 mm diameter, 50 ml capacity). Figures written aside the recorded line show the volume of water filling the cell at each time. These records were taken with reference to the 50 ml water column in another cell. Fig. 2 shows that when the cell is empty, the recording pen runs straight but as the cell is filled with water, the printing of the pen swings laterally until the depth of water reaches a certain threshold value. In this result, it is noticeable that vibration of printing practically vanishes when the cell is filled with 50 ml of water and no vibration when empty. This suggests that vibration of printing is only due to motion of water in the cell and not to mechanical deficit of the instrument.

Fig. 1 being compared with Fig. 2, it is clear that water in the rectangular cuvette is more sensitive to motion. To eliminate this fault, a cylindrical cell was prepared in which water could be completely filled up to the mouth. Fig. 3 shows the result obtained with a pair of closed, cylindrical cells aboard the "Ryofu-maru" under almost the same sea condition as experienced when the

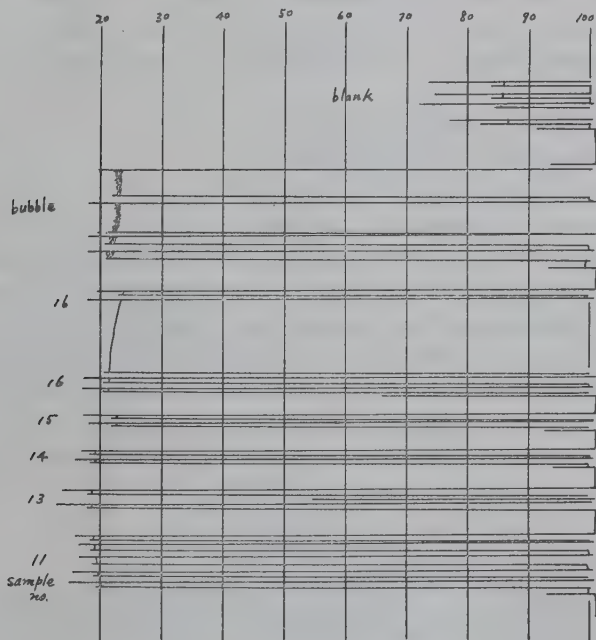


Fig. 3 Record obtained with a pair of closed, cylindrical cells filled up with distilled water or sample water.

result of Fig. 1 was obtained. Fig. 3 shows how good in efficiency to reduce vibration of printing the cylindrical cell is. The printing shown at the middle of Fig. 3 was obtained when an air bubble was left purposely in the cell, where vibration can be seen.

It is well known that the coloration of phospho-molybdate depends on the period during which to set the solution aside after the addition of SnCl_2 solution.²⁾ When the recording photometer is used, the best condition can be easily determined to commence the measurement of absorbancy by finding a plateau on a

curve drawn with the recording pen as shown in Fig. 3.

Suppose there are twenty samples to be analysed. Then, the addition of SnCl_2 solution is done simultaneously to five of them. Wait for five minutes and transfer the first sample into the cell and let the instrument record the absorbancy. When a plateau is found on the record, add the SnCl_2 solution to the next five. Then, after confirmation of the record of the first sample, the sample in the cell is changed with the next one. In such a way the absorbancy of the phospho-molybdate can be recorded under a more satisfactory condition by this instrument.

There is no need to read the absorbancy at every measurement, because it can be read afterwards whenever wanted.

From the discussion it has been recognized that vibration of the recording pen is not due to mechanical deficit but due to structure of the cell.

Now, remarks will be given to comparison of two photocell photometer with one photocell photometer. When a two photocell photometer is in use, unless the standard solution treated in the same way in which the sample waters are done is employed as a reference in place of distilled water, absorbancies of standard solution, NaCl solution or artificial sea water or low phosphate natural sea water and sample waters must be measured separately in reference to distilled water, which is not substantially different from the operation pertaining to the determination by the one photocell photometer.

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The Fluctuation of Hydrographic Conditions in the Sea South of Honshū, Japan (Review)*

By

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(Received May 22, 1963)

1. Introduction

Many oceanographers have studied the fluctuation of the Kuroshio and the cold water mass in the sea south of Honshū, Japan. Recently, the observations were made frequently and a number of reports based on those data have been published. The way of observations remains as it was in general and they have got synoptic results. Though the results are useful in various fields, we could not expect a rapid progress in the study if such a kind of observations would be carried out without definite purposes. Therefore, it is necessary



Fig. 1. Map of the sea area, showing locations mentioned in the paper.

* submitted to the symposium on the hydrographic conditions in the sea south of Honshū, held on March 22, 1962.

to find fluctuations of large scale on the basis of routine observations in each season and, on the other hand, to study special phenomena by making observations proper to researches.

As the study is in such present conditions, it is significant to summarize the results obtained up to date. This requires a great deal of labour and so it will be impossible to aim at the completeness. The general features of the fluctuation are described on the basis of the published papers and the reliable conclusion will be drawn. Moreover, it will be pointed out what remains unsolved. The theoretical discussion on the mechanism are not touched and the fluctuation of small scale is left out of consideration.

The influence of typhoons upon the hydrographic conditions has been discussed in the recent years. This is one of the interactions between the air and the ocean and is a very interesting problem. Here are shown some examples in the region.

2. *The current axis of the Kuroshio*

In the region, we cannot find so remarkable variation in the position of the current axis of the Kuroshio as near the polar front east of Honshū. But sometimes, the position moves in accordance with the fluctuation of the cold water mass off Enshū-nada.

The average position is obtained by NAN'NITI (1960) on the basis of the data from 1931 to 1959. He says that the average position shows a sine-wave of the length of about 1000 km. MASUZAWA (1960) draws a similar average position by using the data from 1954 to 1959. They also get the standard deviation of the fluctuation of the current axis and conclude that the fluctuation is remarkable off Enshū-nada. MORIYASU (1956) gets the similar results about the fluctuation based on the data for only 3 years (from 1954 to 1956). These results are in agreement with each other independently of the period of statistics. NAN'NITI (1960) and MORIYASU (1956) survey the possibility of the statistical forecasting of the position of the current axis, but can find no chance of it. They try to use the correlation and the treatment is very simple. If more advanced procedure is introduced, the statistical treatment would have success.

There are a number of descriptions on the current axis. Especially, the fluctuation after the World War II is described in detail. This is owing to the frequent, accurate observations. UDA (1951) shows the fluctuation south of Daio-saki and of Shiono-misaki from 1936 to 1943. From 1937 to 1942, the cold water mass existed and the current axis was located offshore. The maximum

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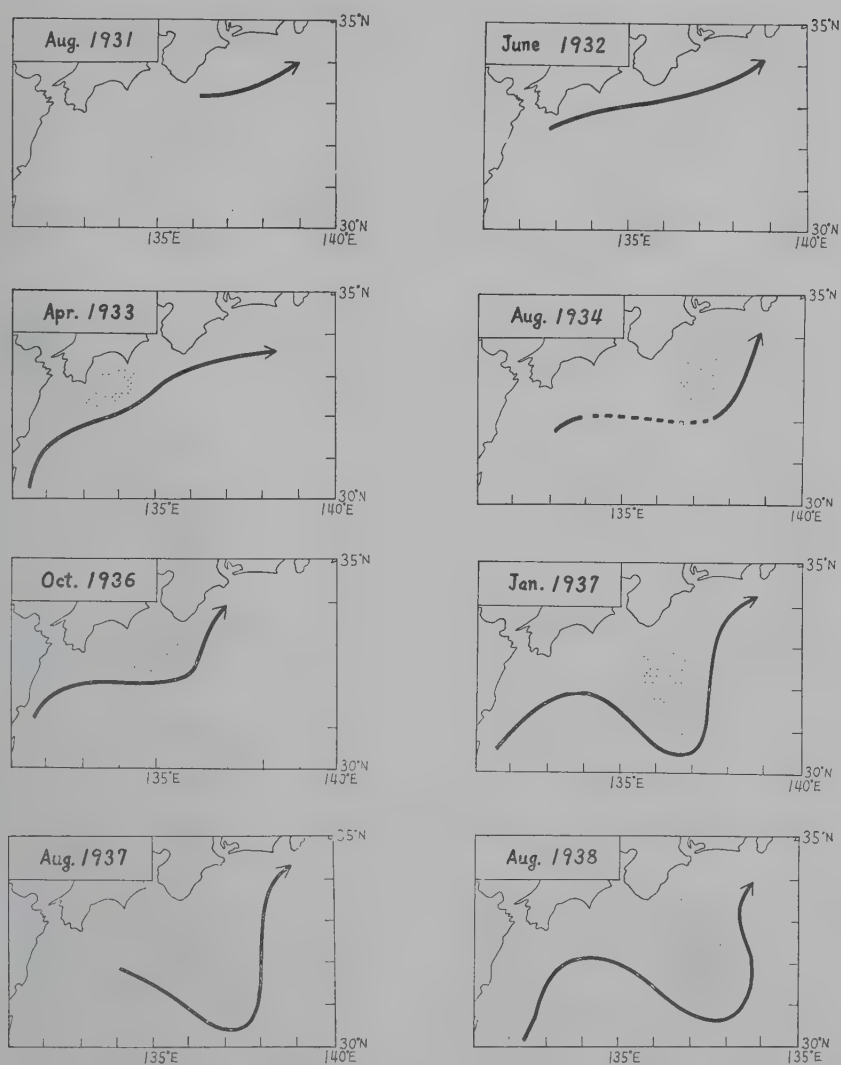
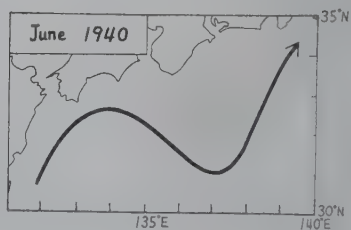
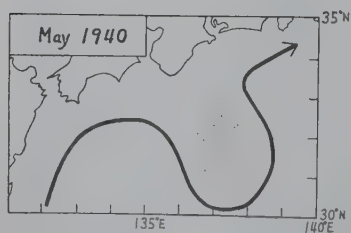
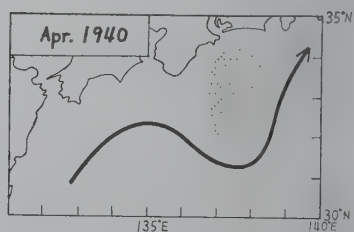
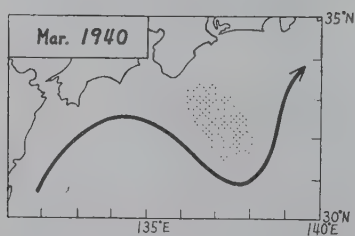
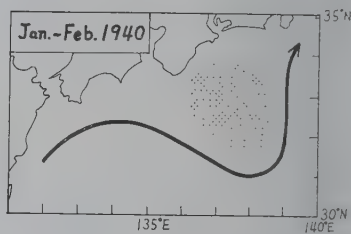
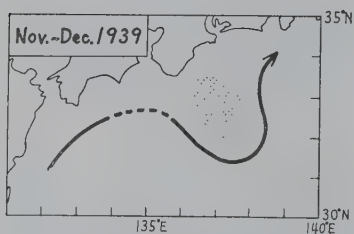
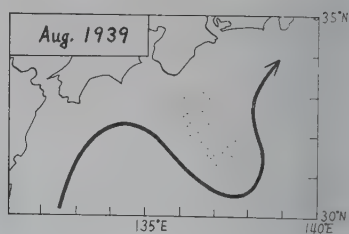
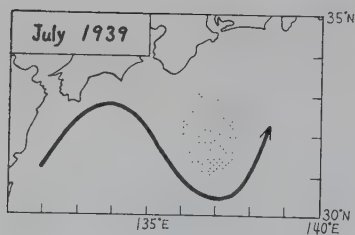


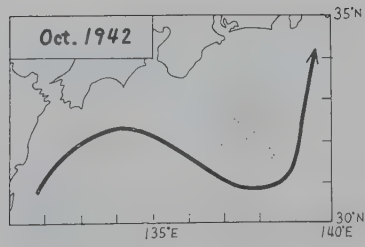
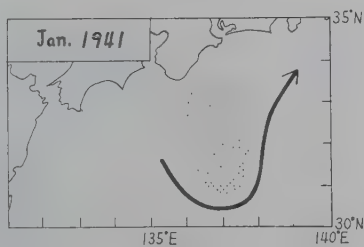
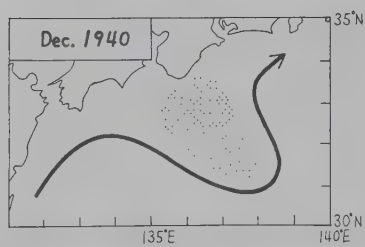
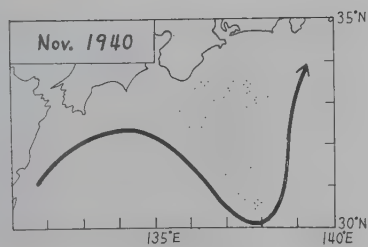
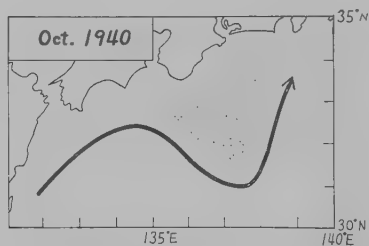
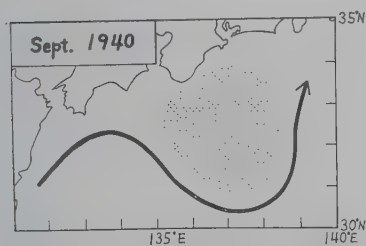
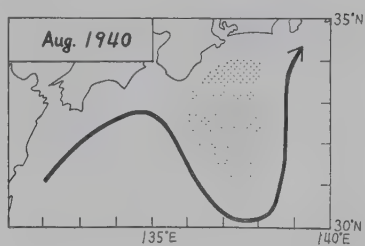
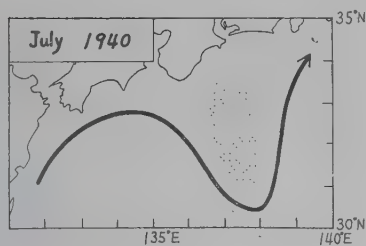
Fig. 2. The current axis of the Kuroshio and the domain of the cold water mass or small cold region.

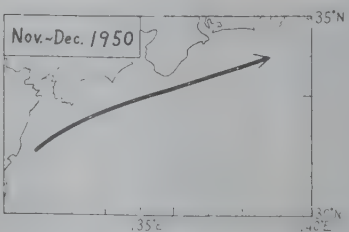
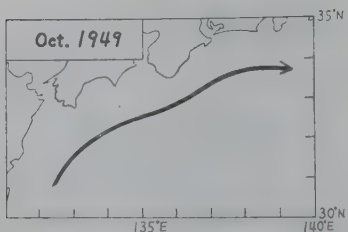
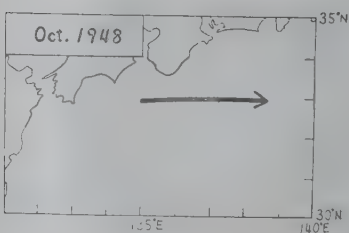
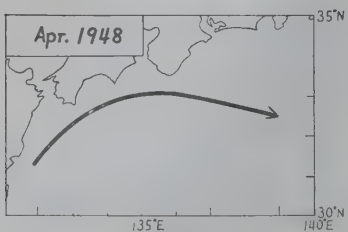
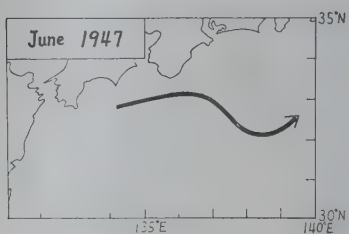
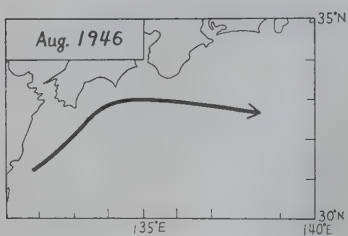
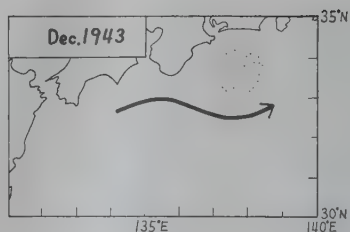
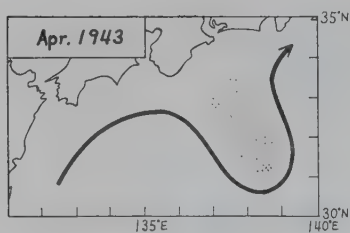
→ : the current axis of the Kuroshio

⋯ : the domain of the cold water mass or small cold region

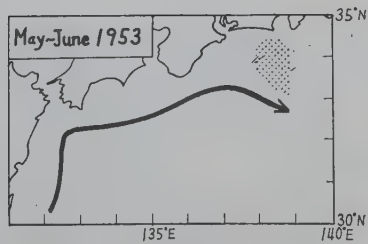
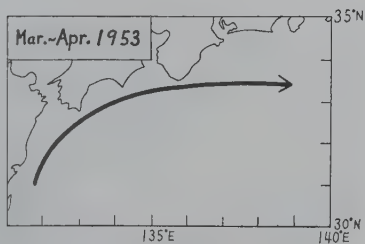
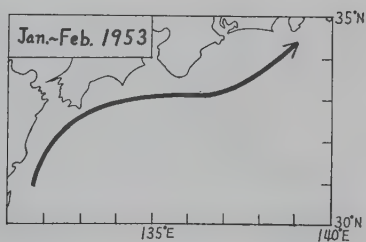
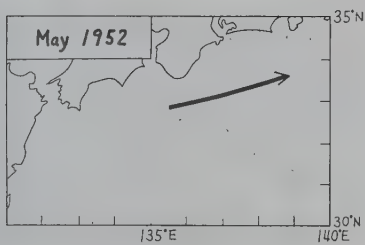
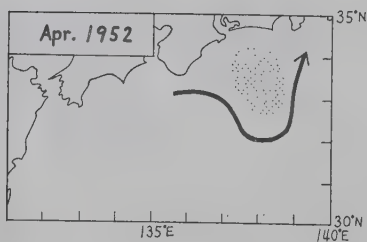
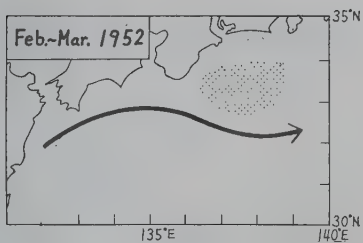
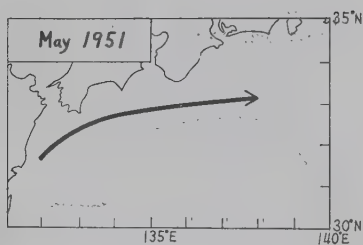
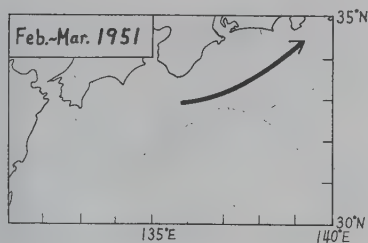


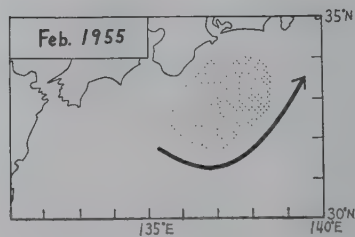
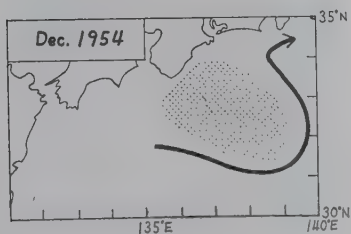
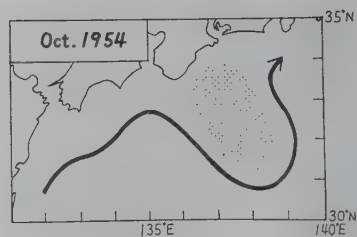
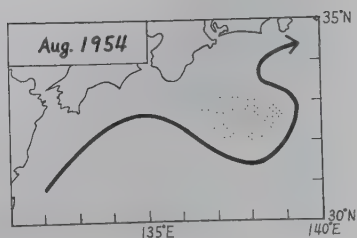
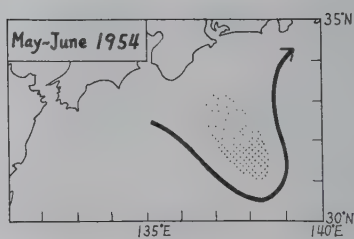
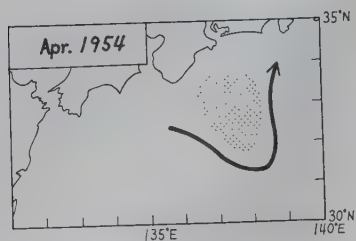
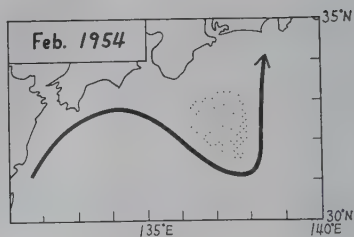
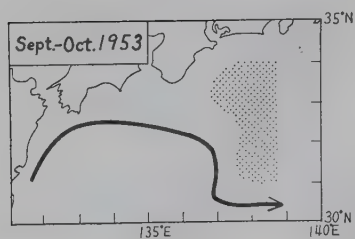
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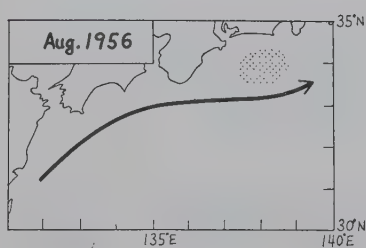
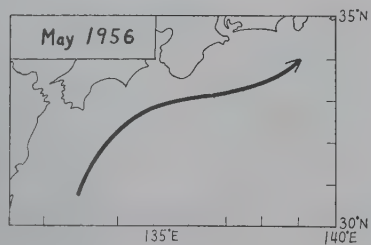
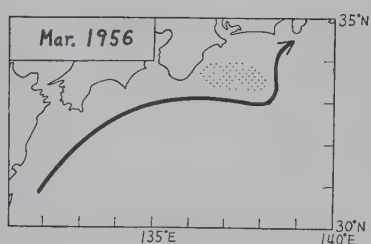
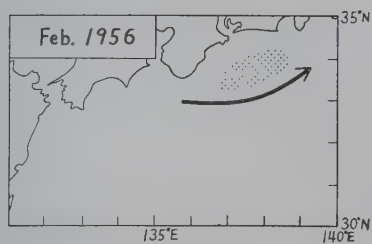
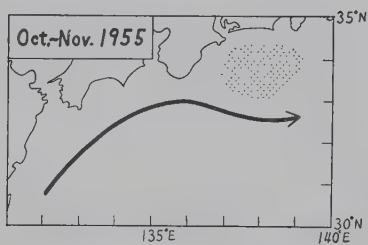
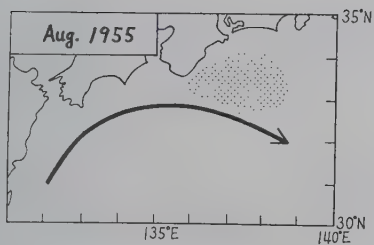
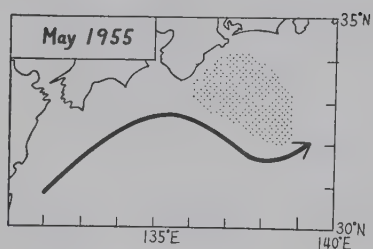
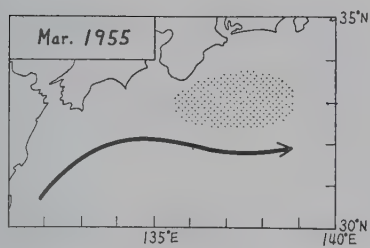


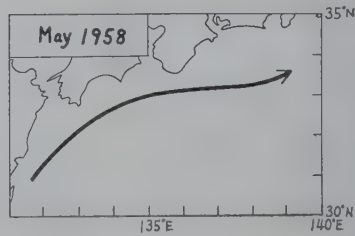
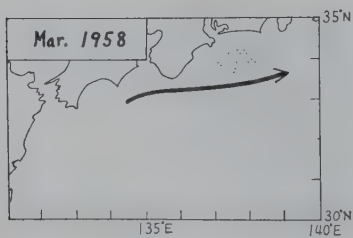
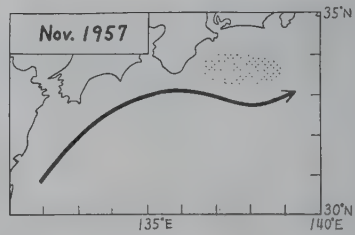
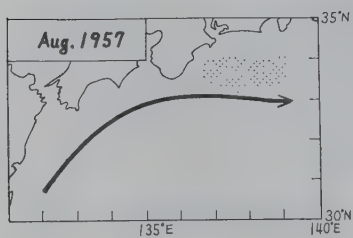
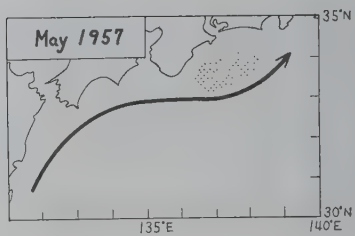
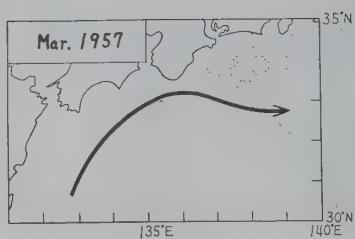
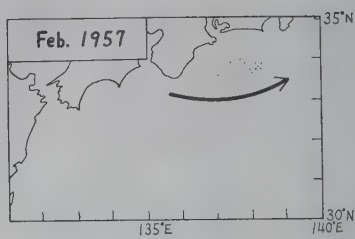
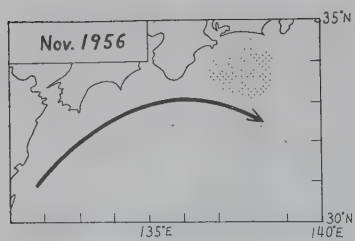
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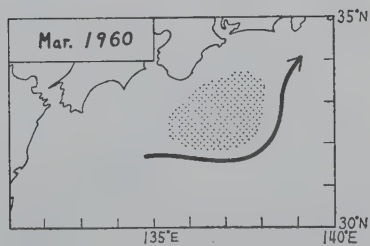
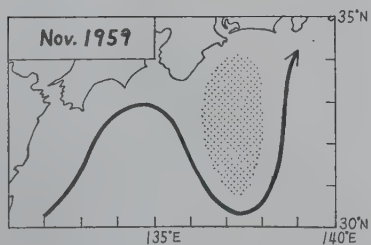
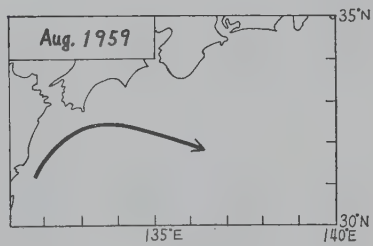
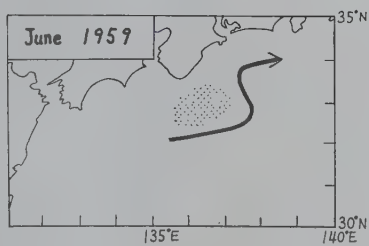
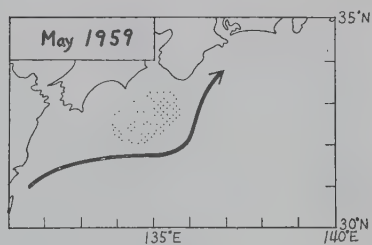
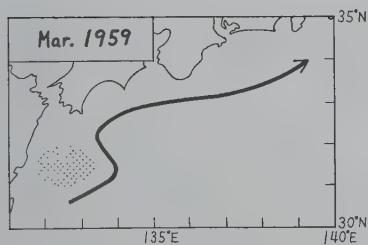
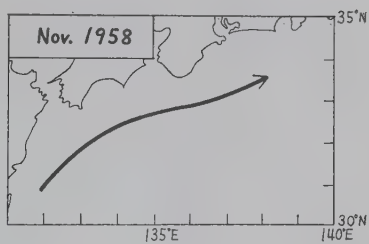
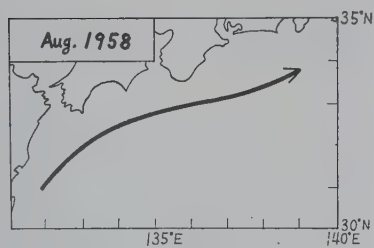


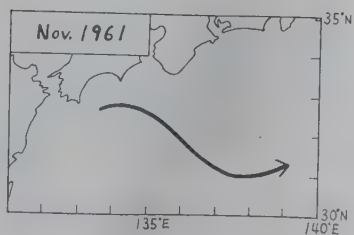
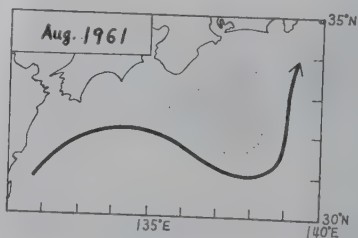
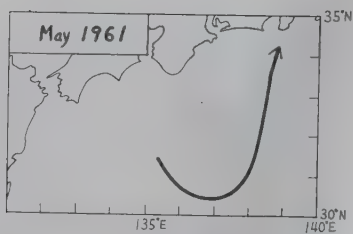
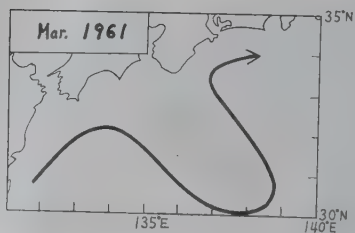
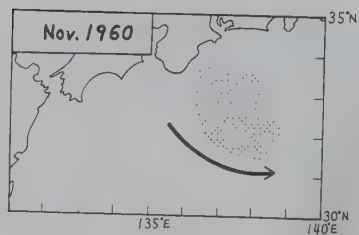
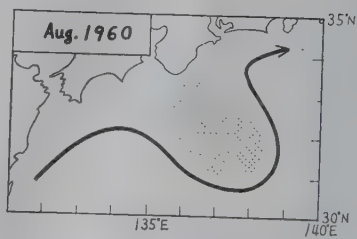
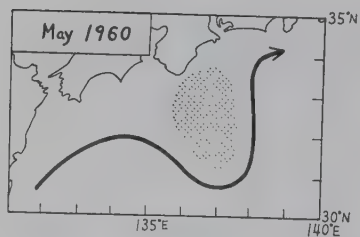
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distance from the coast to the current axis is 280 nautical miles off Daiō-saki and 200 nautical miles off Shiono-misaki. And the minimum is 50 nautical miles and 20 nautical miles off Daiō-saki and off Shiono-misaki, respectively. It may be considered that those are the limit of the fluctuation of the axis in the region. The fluctuation of the current axis from 1950 to 1953 is described by ICHIYE (1952, 1953 a, 1954 a). In this period, the observations were not made systematically and so the study is restricted within narrow area that is mainly south of Shiono-misaki and southeast of Toi-misaki. But, the observations were so frequently made, say, once or twice a month along the same line, that the fluctuation of this scale was made clear for the first time, especially south of the Shiono-misaki where very accurate observations were made on board the ocean weather ship. Though noticeable variations were found temporarily, the current axis was near the coast in general. But, the current axis moved rapidly offshore south of Shiono-misaki in July 1953. This remarkable variation is reported by ICHIYE (1954 a) and MASUZAWA (1954). According to them, the current axis was divided into three branches in June of the year and the main current axis was shifted offshore about 70 nautical miles in July and this pattern was kept till autumn. ICHIYE (1954 a) reports that offshore shifting of the axis was found southeast of Toi-misaki in May of the year and deduces that there might be a connection in the shifting of axis between both places. But, he concludes that the phenomenon must be researched on the basis of sufficient observations. MASUZAWA (1954) suggests that this phenomenon relates with the occurrence of the cold water mass off Enshū-nada. Since 1954, has been made the systematic survey, which covers the region from 131°E to 139°E , north of 30°N and is repeated four times a year. Therefore, the entire pattern has been seen. The axis was far from the coast and the meandering was conspicuous off Enshu-nada till the end of 1955, and such pattern was not seen from 1956 to 1958. In 1959, the axis was offshore southeast of Toi-misaki in May and then the pattern similar to that in 1954~1955 appeared and was kept till 1962. FUKUOKA discussed the fluctuation in series of his papers (for example, 1961). The position of the current axis from 1931 to 1961 is got on reference to the papers of the authors noted above (Fig. 2). This is based upon the surface current velocity with GEK, the dynamic calculation or the water temperature, and some of them are unreliable. From Fig. 2, the fluctuation in the offshore limit of the current axis for each year is got (Fig. 3). The figure shows not only the position of the axis but also its variability for the year. It has to be noticed that remarkable fluctuations occur in C region (from

136°E to 139°E) when the cold water mass exists and the axis is far from the coast. However offshore the axis may be, it can not be expected that the axis is located to the south of 30°N in the region. This is also led from the average

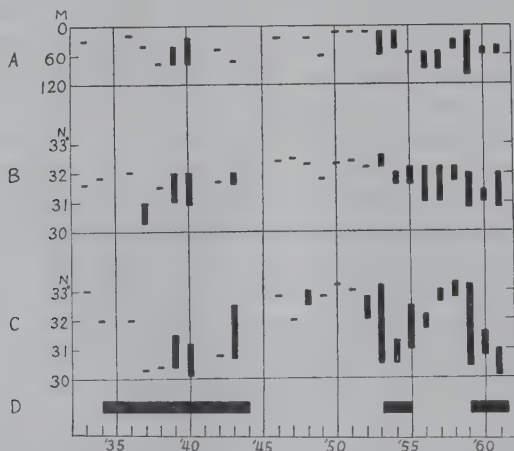


Fig. 3. The fluctuation of the current axis of the Kuroshio.

- A: the distance from the coast to the current axis south-east of Toi-misaki, in nautical miles,
- B: the southern limit of the current axis from 133°E to 136°E in each observation ,
- C: the southern limit of the current axis from 136°E to 140°E in each observation,
- D: the period when the cold water mass appeared, shown with black bars.

position and the standard deviation given by NAN'NITI and MASUZAWA.

The period of the fluctuation of the current axis is also discussed by the authors noted above. As to the fluctuation of large scale, NAN'NITI (1960) finds the period of about 5 years from the data for about 30 years. This may be an apparent value and secular variations are not made clear till the data are accumulated for long years. As to the fluctuation of the scale of one year or so, ICHIYE (1954 a) shows some results. South of Shiono-misaki, the period is 2.5~3 months apparently, but the periodgram or correlogram analysis shows that the fluctuation of 5 month period is most predominant and the one of 2.5

month period is next to it. Moreover, it is deduced that the current axis is offshore off Enshū-nada as the axis is near the coast off Shikoku and the result of harmonic analysis shows the fluctuation of one year and of a half year period. Here, the belt of maximum water temperature at the sea surface or in the layer of 100 m is used for the current axis. The result of the harmonic analysis seems to vary considerably from year to year and it is doubtful if the annual or semi-annual fluctuation appears. The periodicity is an important factor in both the study and the forecasting of such a kind of fluctuation, but finding true periods is very difficult under present conditions.

3. *The cold water mass*

Sometimes, there appears the circular domain called the cold water mass or the cold water region. In the cold water mass, a cyclonic eddy is found and the water temperature is lower. And the Kuroshio flows around the cold water mass and the current axis is found more offshore when the cold water mass exists. The phenomenon was discovered for the first time in 1934 on the basis of oceanographic observations and it was taken to be an abnormal conditions. But, the cold water mass appeared thereafter and, at present, it is concluded that the cold water mass appears periodically.

Now, the fluctuation of the cold water mass is described on reference to the papers of UDA (1949), FUKUOKA (1961) and MORIYASU (1959) etc. The large cold water mass (called by FUKUOKA) is kept for a long time and appeared three times since 1934. The first one was found in 1934 and had the largest area about 1938 and disappeared about 1945. Both the position and the area fluctuated in the 10 years. FUKUOKA (1961) points out that a cyclonic eddy appeared south of Shikoku in 1933. The second one was ascertained in 1954 and decayed in 1956. As stated in the preceding section, the current axis of the Kuroshio moved rapidly offshore south of Shionomisaki in July 1953. So, it may be possible to take that the cold water mass appeared about that time. The third one appeared in 1959 and still existed in 1962. FUKUOKA (1961) also notices a cyclonic eddy south of Shikoku which was found just before the appearance of the cold water mass. MORIYASU (1961) traces the movement of the eddy and suggests that the eddy moved eastward and that the cold water mass was formed from the eddy. In addition to the large cold water mass, the cold water mass of a short life was found in July 1946, June 1947, April 1948 and February~May 1952. The last one is analyzed by YOSIDA (1952). According to him, the Kuroshio flowed to the south of 32°N

in February~March when the cold water mass developed, and the cold water mass almost disappeared in May. Perhaps, the cold water mass of such a short life was missed owing to the shortage of observations and so this appeared more frequently.

The period of the appearance is studied. UDA (1949) finds the period of 10 and 30 years, while NAN'NITI (1958) finds the period of 15 years. The period obtained by them is based upon the data of nearly 30 years and those values require confirmation when the data are accumulated satisfactorily. If the appearance of the cold water mass is related with the fluctuation of the Kuroshio, the period will not be independent of each other.

It is difficult to study the annual variation of the cold water mass, because the observations were not made sufficiently. But, ICHIYE (1954 b) studies the annual variation for 1940, when the observations were carried out in each month. According to him, the cold water mass develops in August~September and decays in April~May, and the semi-annual variation is predominant in the fluctuation of the area, while the annual variation is predominant in the fluctuation of the angular momentum and of the kinetic energy. The results are based upon the dynamic topography at the sea surface referred to the 600 db surface. MORIYASU (1959) researches the fluctuation for 1954~1956 in the similar way, but he uses the dynamic topography at the sea surface referred to the 800 db surface in each season. He says that the cold water mass develops in October~November and decays in August. Though the results seem to contradict each other, it is of no significance to compare the one with the other.

Various elements are used as the indicator of the intensity. The radius at the sea surface is the most useful indicator where the radius is taken as the radius of the circle which has the area of the cold water mass. According to ICHIYE and MORIYASU, the average of the radius is about 100 km or so. And its standard deviation is about 20 km. Though the result shows only a part of the fluctuation of the scale, it may be considered that the cold water mass has the scale noted above.

The position of the cold water mass also fluctuates. To the north and to the east of the cold water mass, there are fixed boundaries, Honshu and the ridge around the meridian of 139°E, and the northward and the eastward extension are restricted by them, while there are no fixed boundaries to the west and to the south and the extension in the direction is free. But, the cold water mass extends neither to the west of 135°E nor to the south of 30°N. The reason

has not been made clear yet and it must be studied dynamically.

The mechanism of the appearance is discussed dynamically, but there is possibility of further study. For the purpose, a new method of observations will be required.

The definition of the cold water mass is indefinite. In this paper, it is considered that the cold water mass exists when the cyclonic eddy extends to the south of 33°N and the Kuroshio flows with noticeable meandering in the region from 135°E to 139°E .

4. The influence of typhoons upon the hydrographic conditions

It is said that the hydrographic conditions are affected by typhoons. Typhoons have strong winds and precipitation, and they cause the variation of the hydrographic conditions. Now, the effect is divided into two, the change in the pattern and the change in the water temperature in the subsurface layer. Some examples in the region will be shown below.

As typhoons are intense cyclones and have strong winds, they give the upheaving owing to low atmospheric pressure and the formation of eddies owing to wind stress. For example (Syoji, 1951), a small cyclonic eddy was found around 32°N , $132^{\circ}30'\text{E}$ after the passage of the typhoon. This eddy was not found before the passage of the typhoon and the interval of observations was only 5 days. And there were found noticeable changes in the water temperature and chlorinity from the sea surface to the depth of 400 m. Some say that the cold water mass is formed under the influence of typhoon, but it seems not to be appropriate. ICHIE (1955) shows that a small cold water mass is produced by cyclones and that its life is 5~10 days. MASUZAWA (1950) shows an example of the variation in water temperature and chlorinity and concludes that it is caused by the movement of the water mass owing to the typhoon.

The variation of the water temperature in the subsurface layer is seen easily with BT and studied in detail recently. OGATA (1960) shows that the surface water temperature was decreased by the passage of the typhoon and that it took about two weeks for the temperature to recover. KONAGA (1960) shows the fall of the chlorinity in addition to the water temperature in the subsurface layer. According to them, the amount of the fall of the surface water temperature is $2\sim 3^{\circ}\text{C}$ and the fall is caused by intense evaporation. KONAGA concludes that the strong precipitation caused the fall of the chlorinity in the subsurface layer. Though the analysis is carefully made in these studies,

the detailed discussion requires more systematic observations.

The hydrographic conditions are changed by typhoons as shown above, while there are some cases where the influence is obscure. If there appears the change in the hydrographic conditions after the passage of typhoon, it must be carefully inspected whether the change is caused directly by the typhoon or not.

5. Concluding remarks

No new results are derivad in this paper, but the results reported by various authors are summarized. Though some of the results may be missed, the main features are shown. As seen in the above description, the shortage of data often forces speculation upon us. This is inevitable in some cases, but it is to be hoped that the discussion is made on the basis of sufficient data. Observations must be planned so that they may contribute to the purpose, while the obtained data can be used for other purposes and their publication is also important. Furthermore, co-operative surveys are necessary for detailed discussion. These will make it possible to discuss on the fluctuation without speculating and then theoretical considerations will advance remarkably based on solid facts.

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Theoretical Investigations of Typhoon Surges along the Japanese Coast (III)

By

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(Received July 9, 1963)

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Chapter 6. The western part of Inland Sea

We reported the theoretical investigations of Storm Surges in Ise Bay,¹⁾ Tokyo Bay¹⁾ and Osaka Bay.²⁾ This time the authors investigated the storm surges in the Western Part of Inland Sea,³⁾ using the same rotational theory as in chapter 4,²⁾ where the storm surges in Osaka Bay were studied.

6.1 The first step computation "WAS"

In the preceding case, however, the authors pointed out that the mouth conditions were very important. So, in this case, the author first computed the

storm surges in the open sea off the south of Shikoku (Fig. 6.1). This area is so extended that the depth in the most southern part becomes 4,000 m, where, by our assumption, the surges are always equal to the statical water elevation corresponding to the atmospheric air pressure fall. We also provided that the Straits of Hayasui and Kii are closed and that the bottom stress is neglected because of the the deep sea area. The authors named this program "WAS", which has 87.5 sec. time step and 15 Km mesh interval.

6.2 The second step computation "SAS"

Using the computed surges at the Strait of Hayasui in "WAS" as the mouth conditions for the second step computation, the authors studied the Western Part of Inland Sea. (Fig. 6.1) Here we provided that the Strait of Kurushina is closed and that the Strait of Hayatomo is open to the Japan Sea, where, by our assumption, the surges are always equal to the statical water elevation corresponding to the atmospheric air pressure fall. The authors named this program "SAS", which has 60 sec. time step and 5 Km mesh interval.

6.3 The computed models

The authors computed the following 9 Models for both "WAS" and "SAS". (Tab. 6.1) Each typhoon course is shown in Fig. 6.1.

Table 6.1. Models for "WAS" and "SAS".

Model No.	Typhoon	Course	Period
1	Suwo	Suwo	1942 Aug. 27—28
2	Ruth	Ruth	1951 Oct. 14—15
3	Toya	Toya	1954 Sept. 26
4	5522	5522	1955 Sept. 29
5	Suwo	Ruth	} Imaginary models
6	Suwo	Toya	
7	Ise	Suwo	
8	Ise	Ruth	
9	Ise	Toya	

6.4 Results

Comparisons of weather elements and surges between observed and computed at Shimonoseki, which locates near the Strait of Hayatomo, are shown in Fig.

6.2 and Fig. 6.3 in the case of Model 1, Model 2 and Model 3. According to Fig. 6.3, we cannot say the computed surges are in good agreement with the observed. One of most important factors which cause these disagreement is, the authors think, the tide. In fact, Tide Table, published by the Maritime Safety Board, says that near the Strait of Hayatomo the spring range comes to 3.1 m and its current velocity 7 Kt, and that near the Strait of Hayasui they are 1.7 m and 6 Kt. So the influences of the tide and typhoons to the movement of sea water in this area will be comparable in force. We must have the tidal phenomena under consideration in the case of storm surge computations for such the area.

Chapter 7. Ariake Bay

Following the preceding computations, the authors investigated the storm surges in Ariake Bay,⁴⁾ which lies in the "typhoon way" and by surges the coast is most frequently attacked in Japan. Besides, this bay is well-known for the great range of tides, that is, at the head of bay, it reaches almost 6.0 m and even at the mouth 3.0 m in the spring tides. Hence, even under the typhoon, what rules the motion of sea water in this bay is the tides. So the authors were greatly interested in this work, and at the same time we must necessarily solve the problem pointed out in the preceding chapter. The concerning areas and typhoon courses in this computation are shown in Fig. 7.1.

7.1 The first step computation "WAR"

To estimate the surges at the mouth of bay, the authors first computed the surges in the open-sea area off the western coast of Kyushu, including Ariake Bay, but not Yatsushiro Bay. Our assumptions are, in this case, that the surges on the western and southern border lines of this area are always equal to the statical water elevation corresponding to the atmospheric air pressure fall, and that Yatsushiro Bay is closed to both the open sea and Ariake Bay. The authors named this program "WAR", which has 50 sec. time step and 6.75 Km mesh interval. (Fig. 7.2)

7.2 The computation for the tides "TAR"

In the cases of second step computations, hitherto, we always provided that the initial values of surges and current velocities are zero in whole the bays, and that the variations of surges at the mouths are that of in the first step.

These assumptions, however, are not reasonable in this computation as mentioned above. Hence we must compute tides in this bay at the initial time before we enter into the second step. Giving the spring range to the mouth we computed the distribution of the tidal current and sea level in Ariake Bay till the time when the second step begun. The authors named this program "TAR", which has 42.85 sec. time step and 2.25 Km mesh interval. (Fig. 7.3)

7.3 The second step computation "SAR"

The condition for mouth is the variation of the surges obtained from "WAR" and the spring tidal range. The initial condition is as mentioned above. In this way, if we change the initial condition, we can compute the storm surges under the various tidal phenomena, that is, surges in the ebb or flood tide. The authors named this program "SAR", which has the same time step and mesh model as that of "TAR".

7.4 The computed models

The authors computed the following 9 Models. (Tab. 7.1) Each typhoon course is shown in Fig. 7.1.

Table 7.1. Models for "WAR" and "SAR".

Model	No.	Typhoon	Course	Tide	Remarks
WAR	1	1927	1927	H. W.	
	2	1942	1942	"	Imaginary model
	3	5609	5609	"	
SAR	4	Ise	1942	"	Imaginary model
	5	Ise	Kezia	"	"
	6	Ise	5609	"	"
SAR	7	1942	1942	L. W.	
	8	Ise	1942	H. W.	} Closed by dike Imaginary models
	9	Ise	5609	H. W.	

7.5 The equations of motion and continuity

Let the origin and the axes x, y be in the surface when there is no disturbances and let the axis z be vertical and downwards. (Fig. A) If this system is rotating with constant angular velocity ω' about the axis of z , the equation of motion for the fluid in this system becomes

$$\frac{DU}{Dt} + 2\omega \times U + \omega \times (\omega \times r) = K - \frac{1}{\rho_{10}} \text{grad } P^* + \frac{1}{3} \nu^* \text{grad div } U + \nu^* \Delta U, \quad (7.1)$$

(34)

$U(u, v, w)$; the velocity vector of fluid at any point A,
 $\omega(0, 0, \omega')$; the rotational vector of system,
 $r(x, y, z)$; the vector showing the position at A,
 $K(0, 0, g)$; the external force acting a unit mass of fluid, g means
 the gravity acceleration,
 P^* ; the pressure at A,
 ρ_w ; the density of fluid,
 ν^* ; the coefficient of eddy viscosity.

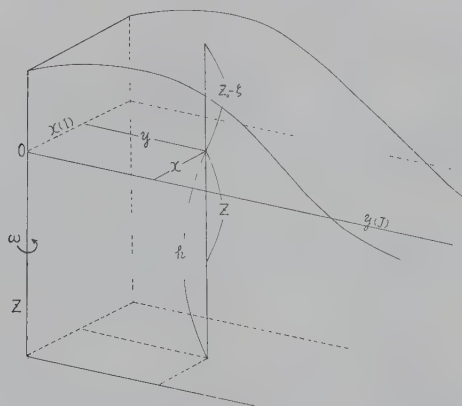


Fig. A. The co-ordinate system.

Now we provide that

(a) $\operatorname{div} U=0$,

$$(b) \quad \frac{DU}{Dt} = \frac{\partial U}{\partial t}.$$

According to our linear computation, the ratio: $|\mathbf{U} \text{grad } \mathbf{U}| / \left| \frac{\partial \mathbf{U}}{\partial t} \right|$ becomes almost 1 at the mouth of bay and 0.26 at the center. It is indeed that the non-linear terms are very important, but they cause trouble in numerical computation. We leave this problem in the future studies.

$$(c) \quad \frac{P^*}{\rho w} = \frac{P}{\rho w} + g(z + \zeta) + \frac{\omega^2}{2}(x^2 + y^2),$$

where

P ; the air pressure,

 ξ ; the elevation of surface (upwards).

(d) P can be expressed in the formula (7.7).

$$\therefore \text{grad } P = \frac{a}{r_0^2} \left[1 + \left(\frac{r}{r_0} \right)^2 \right]^{-\frac{3}{2}} \mathbf{r}.$$

(e) $f = 2\omega' = 2\omega \cos \varphi$,

φ is the latitude of the computed area, ω the angular velocity of the Earth's spin.

(f) The components of $\mathbf{v}^*$ are (v, L, L) .

On these suppositions we get the following equations of motion and continuity.

$$\left. \begin{aligned} \frac{\partial u}{\partial t} &= fv - g \frac{\partial \zeta}{\partial x} - Tx + \nu \frac{\partial^2 u}{\partial z^2} + L \Delta_1 u, \\ \frac{\partial v}{\partial t} &= -fu - g \frac{\partial \zeta}{\partial y} - Ty + \nu \frac{\partial^2 v}{\partial z^2} + L \Delta_1 v, \\ \frac{\partial u}{\partial x} + \frac{\partial v}{\partial y} + \frac{\partial w}{\partial z} &= 0, \end{aligned} \right\} \quad (7.2)$$

where

$$T = \frac{a}{\rho_0 r_0^2} \left[1 + \left(\frac{r}{r_0} \right)^2 \right]^{-\frac{3}{2}}; \quad \Delta_1 = \frac{\partial^2}{\partial x^2} + \frac{\partial^2}{\partial y^2}.$$

7.6 The fundamental equations

To solve the equations (7) directly we have not enough knowledge about $u(z)$, $v(z)$, yet. But if we use the following functions

$$\left. \begin{aligned} M &= \int_{-\zeta}^h u dz = (h + \zeta) \bar{u}, \\ N &= \int_{-\zeta}^h v dz = (h + \zeta) \bar{v}, \end{aligned} \right\} \quad (7.3)$$

where, $\mathbf{U}(u, v)$ means the mean velocity of fluid, and the terms below the second order are neglected, the equations (7.2) become

$$\left. \begin{aligned} \frac{\partial M}{\partial t} &= fN - g(h + \zeta) \frac{\partial \zeta}{\partial x} - (h + \zeta)Tx + \nu \frac{\partial u}{\partial x} \Big|_{-\zeta}^h + L \Delta_1 M, \\ \frac{\partial N}{\partial t} &= -fM - g(h + \zeta) \frac{\partial \zeta}{\partial y} - (h + \zeta)Ty + \nu \frac{\partial v}{\partial y} \Big|_{-\zeta}^h + L \Delta_1 N, \\ \frac{\partial \zeta}{\partial t} &= - \left(\frac{\partial M}{\partial x} + \frac{\partial N}{\partial y} \right). \end{aligned} \right\} \quad (7.4)$$

Now we adopt the following frictional law:

at the surface

$$\nu \frac{\partial u}{\partial z} \Big|_{-\xi} = \tau_s^u = \rho_a \gamma^2 W_x |W|,$$

$$\nu \frac{\partial v}{\partial z} \Big|_{-\xi} = \tau_s^v = \rho_a \gamma^2 W_y |W|,$$

at the bottom

$$\nu \frac{\partial u}{\partial z} \Big|_h = \tau_b^u = -\rho_a \gamma^2 \bar{u} |U| + k \tau_s^u,$$

$$\nu \frac{\partial v}{\partial z} \Big|_h = \tau_b^v = -\rho_a \gamma^2 \bar{v} |U| + k \tau_s^v,$$

(7.5)

where

ρ_a ; the density of air,

$W(W_x, W_y)$; the wind velocity,

$\gamma^2 = 2.6 \times 10^{-3}$, $k = 0.25$.

The final forms of fundamental equations that we can use in the numerical computations for the storm surges are:

$$\left. \begin{aligned} \frac{\partial M}{\partial t} &= fN - g(h + \xi) \frac{\partial \xi}{\partial x} - \gamma^2 \frac{Q}{(h + \xi)^2} M - (h + \xi)Tx + \frac{1+k}{\rho_w} \rho_a \gamma^2 R + L\Delta_1 M, \\ \frac{\partial N}{\partial t} &= -fM - g(h + \xi) \frac{\partial \xi}{\partial y} - \gamma^2 \frac{Q}{(h + \xi)^2} N - (h + \xi)Ty + \frac{1+k}{\rho_w} \rho_a \gamma^2 S + L\Delta_1 N, \\ \frac{\partial \xi}{\partial t} &= -\frac{\partial M}{\partial x} - \frac{\partial N}{\partial y}, \end{aligned} \right\} \quad (7.6)$$

where,

$$Q = \sqrt{M^2 + N^2},$$

$$R = W_x |W|, \quad S = W_y |W|,$$

$$T = \frac{a}{\rho_w r_0^2} \left[1 + \left(\frac{r}{r_0} \right)^2 \right]^{-\frac{3}{2}}$$

$$k = 0.25, \quad \gamma^2 = 2.6 \times 10^{-3}, \quad L = 10^5 \sim 10^6.$$

Using the equations (7.6), if we can know the distribution of wind and pressure, M , N and ξ will be numerically computed.

7.7 The meteorological conditions

(a) The distribution of air pressure

We express the distribution of air pressure in the area under the typhoon by the simple formula containing some unknown constants which are decided by the observation. The adopted formula is

$$Ps = P_{\infty} - a / \sqrt{1 + (r/r_0)^2}, \quad (7.7)$$

where

r ; the distance between the center of typhoon and at any point A (x, y),

Ps ; the air pressure on the sea surface at A (x, y),

P_{∞} ; the air pressure in the area out of the typhoon,

a ; the pressure fall of the center of typhoon from P_{∞} ,

r_0 ; a unknown constant refering to the scale of typhoon,

Three unknown constants P , a and r_0 we must decide by the observation.

(b) *The distribution of wind*

We provided that the wind $\mathbf{W}$ (W_x, W_y) in the area under the typhoon consists of two elements, the field wind $\mathbf{F}$ and the gradient wind $\mathbf{G}$. (Fig. B) The direction of $\mathbf{F}$ coincides with that of typhoon's velocity $\mathbf{V}$ (V_x, V_y) and the speed is inversely proportional to the distance r from the center of typhoon. $\mathbf{G}$ takes the direction inwards at an angle of 30° with the isobar, and the speed is proportional to the gradient of air pressure which is computed with the formula (7.7). In this way the expression for $\mathbf{W}$ is

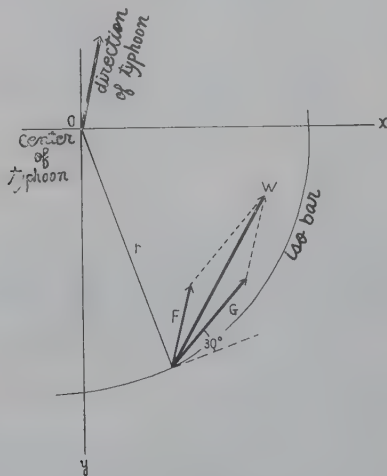


Fig. B. The wind system.

$$\left. \begin{aligned} Wx &= C_1 V_a \exp \left(-\frac{r\pi}{5 \times 10^7} \right) - \left[C_2 \sqrt{\frac{10^8}{\rho a}} \frac{1}{r_0} z^{\frac{3}{2}} - C_2 \frac{f}{2} a^{-\frac{1}{2}} \right] a^{\frac{1}{2}} (0.500x - 0.866y), \\ Wy &= C_1 V_a \exp \left(-\frac{r\pi}{5 \times 10^7} \right) - \left[C_2 \sqrt{\frac{10^8}{\rho a}} \frac{1}{r_0} z^{\frac{3}{2}} - C_2 \frac{f}{2} a^{-\frac{1}{2}} \right] a^{\frac{1}{2}} (0.500x - 0.866y), \end{aligned} \right\} (7.8)$$

where

$$Z = [1 + (r/r_0)^2]^{-\frac{1}{2}},$$

and C_1 , C_2 are constants which are reasonably supposed according to each typhoon. (Table 7.2)

Table 7.2. The constants of typhoon.

Typhoon	a (mb)	r_0 (km)	P (mb)	C_1	C_2
1927	32	30	1011	6/7	0.6
1942	52	70	1005	4/7	0.6
5609	50	110	1013	4/7	0.6
Ise	70	75	1010	4/7	0.6

(c) The courses of typhoons

Fig. 7.1 shows the courses of typhoon. In our computation, using the observed every hour depth and position of the center of typhoon and interpolating them every ten minutes, we give the air pressure and wind, every ten minutes at all the mesh points, according to the formulas (7.8) for the period of typhoon's passage.

(d) Comparisons between the observed and computed weather elements

Fig. 7.4 shows the typhoon's pressure distribution with the distance r and Fig. 7.5 the variations of air pressure and wind at Saga located near the head of bay.

7.8 The finite differential equations for the storm surges

(a) The finite difference

Let $F_{i,j}^t$ be the value of a function $F(x, y, t)$ at a mesh point x_i, y_i and time t , and $x_{i+1} - x_{i-1} = y_{j+1} - y_{j-1} = \Delta s$, $t_{\tau+1} - t_{\tau-1} = \Delta t$. Then the differential coefficients are approximately expressed with the finite difference as follows:

$$\begin{aligned} \left(\frac{\partial F}{\partial x} \right)_{i,j}^{\tau} &= \frac{F_{i+1,j}^{\tau} - F_{i-1,j}^{\tau}}{\Delta s}, \quad \left(\frac{\partial F}{\partial t} \right)_{i,j}^{\tau} = \frac{F_{i,j}^{\tau+1} - F_{i,j}^{\tau-1}}{\Delta t} \\ \left(\frac{\partial^2 F}{\partial x^2} \right)_{i,j}^{\tau} &= \frac{1}{(\Delta s)^2} (F_{i+2,j}^{\tau} - F_{i,j}^{\tau} + F_{i-2,j}^{\tau}) \end{aligned}$$

(b) *The numerical computation formula for the Surge ζ*

With the notation mentioned above, we get from the third equation of formula (7.6)

$$\zeta_{i,j}^{\tau+1} = \zeta_{i,j}^{\tau-1} - [X_{i+1,j}^{\tau} - X_{i-1,j}^{\tau} + Y_{i,j+1}^{\tau} - Y_{i,j-1}^{\tau}], \quad (7.9)$$

where

$$X_{i,j}^{\tau} = M_{i,j}^{\tau} \frac{dt}{ds}, \quad Y_{i,j}^{\tau} = N_{i,j}^{\tau} \frac{dt}{ds}.$$

(7.9) shows that, if we know $\zeta_{i,j}^{\tau-1}$ and $X_{i\pm 1,j}^{\tau}$, $Y_{i,j\pm 1}^{\tau}$, we can numerically compute $\zeta_{i,j}^{\tau+1}$ with this formula.

(c) *The numerical computation formula for X , Y .*

In the same way, from the first equation of (7.6), excepting the term d_i ,

$$\begin{aligned} \frac{X_{i,m}^{\tau} - X_{i,m}^{\tau-2}}{dt} = & fY_{i,m}^{\tau} - g \frac{dt}{ds} (h + \zeta)_{i,m}^{\tau-1} \frac{\zeta_{i+1,m}^{\tau-1} - \zeta_{i-1,m}^{\tau-1}}{ds} - \gamma^2 \frac{Q_{i,m}^{\tau-1}}{[(h + \zeta)_{i,m}^{\tau-1}]^2} X_{i,m}^{\tau-1} \\ & - \frac{dt}{ds} (h + \zeta)_{i,m}^{\tau-1} [T]_{i,m}^{\tau-1} x_{i,m}^{\tau-1} + \frac{1+k}{\rho_w} \rho_a \gamma^2 \frac{dt}{ds} R_{i,m}^{\tau-1}. \end{aligned}$$

If we put

$$Y_{i,m}^{\tau-1} \approx Y_{i,m}^{\tau-2},$$

$$X_{i,m}^{\tau-1} \approx (X_{i,m}^{\tau} + X_{i,m}^{\tau-2})/2,$$

$$Q_{i,m}^{\tau-1} \approx Q_{i,m}^{\tau-2} = \sqrt{(X_{i,m}^{\tau-2})^2 + (Y_{i,m}^{\tau-2})^2} \frac{ds}{dt} = \frac{ds}{dt} Q_{i,m}^{\tau-2},$$

the formula for $X_{i,m}^{\tau}$ to be used in the numerical computation is obtained. In the same way we get the expression for $Y_{i,m}^{\tau}$, and neglecting the small quantity below the second order, they are

$$X_{i,m}^{\tau} = A_{i,m}^{\tau} X_{i,m}^{\tau-2} + f dt Y_{i,m}^{\tau-2} - B_{i,m}^{\tau-1} [\zeta_{i+1,m}^{\tau-1} - \zeta_{i-1,m}^{\tau-1}] - C_{i,m}^{\tau-1} [Tx]_{i,m}^{\tau-1} + DR_{i,m}^{\tau-1}, \quad (7.10)$$

$$Y_{i,m}^{\tau} = A_{i,m}^{\tau-2} Y_{i,m}^{\tau-2} - f dt X_{i,m}^{\tau-2} - B_{i,m}^{\tau-1} [\zeta_{i,m+1}^{\tau-1} - \zeta_{i,m-1}^{\tau-1}] - C_{i,m}^{\tau-1} [Ty]_{i,m}^{\tau-1} + DS_{i,m}^{\tau-1},$$

where

$$A_{i,m}^{\tau-2} = \left[1 - \frac{\gamma^2 ds}{2} \frac{Q_{i,m}^{\tau-2}}{[(h + \zeta)_{i,m}^{\tau-1}]^2} \right] / \left[1 + \frac{\gamma^2 ds}{2} \frac{Q_{i,m}^{\tau-2}}{[(h + \zeta)_{i,m}^{\tau-1}]^2} \right],$$

$$B_{i,m}^{\tau-1} = g \left(\frac{dt}{ds} \right)^2 (h + \zeta)_{i,m}^{\tau-1} \left[1 + \frac{\gamma^2 ds}{2} \frac{Q_{i,m}^{\tau-2}}{[(h + \zeta)_{i,m}^{\tau-1}]^2} \right],$$

$$C_{i,m}^{\tau-1} = \frac{(dt)^2}{ds} (h + \zeta)_{i,m}^{\tau-1},$$

$$D = \frac{1+k}{\rho_w} \rho_a \gamma^2 \frac{(\Delta t)^2}{\Delta s},$$

$$(h + \zeta)_{l,m}^{\tau-1} = h_{l,m}^{\tau-1} + \frac{1}{4} [\zeta_{l+1,m}^{\tau-1} + \zeta_{l-1,m}^{\tau-1} + \zeta_{l,m+1}^{\tau-1} + \zeta_{l,m-1}^{\tau-1}].$$

According to the formulas (7.10), if we know $X_{l,m}^{\tau-2}$, $Y_{l,m}^{\tau-2}$ and $\zeta_{l \pm 1, m \pm 1}^{\tau-1}$ (which are given by the initial conditions) and $T_{l,m}^{\tau-1}$, $R_{l,m}^{\tau-1}$ (which are given by the meteorological conditions), we can compute $X_{l,m}^{\tau}$, $Y_{l,m}^{\tau}$. Combining the formulas (7.9) and (7.10), we can compute $(X_{l,m}^{\tau}, Y_{l,m}^{\tau})$ and $\zeta_{i,j}^{\tau+1}$ alternatively with τ , where mesh points (l,m) and (i,j) are adjoining each other.

(d) *The horizontal mixing computation*

After doing several times computation mentioned above, we execute the calculation for the remaining equations,

$$\frac{\partial X}{\partial t} = L \Delta_1 X,$$

$$\frac{\partial Y}{\partial t} = L \Delta_1 Y.$$

They lied with the finite difference,

$$\left. \begin{aligned} X_{l,m}^{\tau+1} &= \left[1 - 4 \frac{L \Delta T}{(ds)^2} \right] X_{l,m}^{\tau} + \frac{L \Delta T}{(ds)^2} [X_{l+2,m}^{\tau} + X_{l-2,m}^{\tau} + X_{l,m+2}^{\tau} + X_{l,m-2}^{\tau}], \\ Y_{l,m}^{\tau+1} &= \left[1 - 4 \frac{L \Delta T}{(ds)^2} \right] Y_{l,m}^{\tau} + \frac{L \Delta T}{(ds)^2} [Y_{l+2,m}^{\tau} + Y_{l-2,m}^{\tau} + Y_{l,m+2}^{\tau} + Y_{l,m-2}^{\tau}]. \end{aligned} \right\} \quad (7.11)$$

(e) *The conditions for the dike*

Finally the authors discussed the case where the bay is closed by the dike

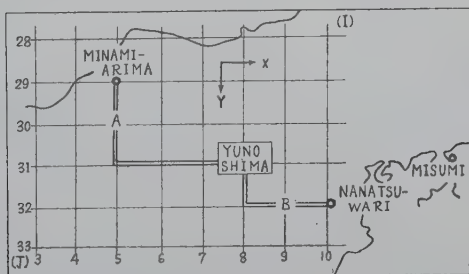


Fig. C. The situation of dike.

which joins Minamiarima, Yunoshima and Nanatsuwari with the two mouths. (Fig. C) The authors computed this models on the assumption that the dike has no influence on the surges and tides at the mouth of bay, that the normal components of current velocity to the dike are zero, and that at the mouth of dike the currents are expressed by the formula

$$V = k\sqrt{2g|\zeta_{EX} - \zeta_{IN}|},$$

where k is given 0.75.

Table 7.3. Maximum Storm Surge (I).

Dike Tide Typhoon	Open High water 1927			Open High water 1942			Open Low water 1942			Open High water 5609			
St. No.	h	m	cm	h	m	cm	h	m	cm	h	m	cm	
1	9	10	44	20	20	73	20	20	73	5	00	75	
2	11	00	43	20	00	66	21	40	80	5	20	69	
3	11	00	52	20	20	73	20	20	90	6	40	80	
4	11	20	43	22	00	80	21	40	91	6	40	86	
5	11	20	66	20	40	86	21	20	110	2)	6	40	94
6	11	40	84	21	00	126	21	10	170	3)	6	00	137
7	11	40	76	21	00	137	—	—	—	4)	6	00	143
8	10	20	72	21	00	132	21	20	142	6	00	136	
9	1) 10	20	66	21	00	150	8) 21	40	180	5) 6	00	152	
10	10	40	38	20	00	180	9) 20	20	98	6) 4	20	207	
11	10	40	34	20	00	222	20	20	140	5	00	245	
12	8	40	38	20	00	157	22	00	169	4	40	172	
13	10	20	88	19	20	130	16	00	83	4	20	200	
14	10	10	43	21	00	108	21	40	136	6	20	103	
15	10	40	62	21	40	112	16	20	76	7)	7	00	105
16	11	00	57	21	20	106	21	20	127	7	20	104	
17	11	40	58	21	20	98	21	00	117	6	40	100	
Observation	1) 10	30	61				8) 20	00	120	2) 6	00	109	
							9) 20	00	139	3) 6	00	130	
										4) 7	00	202	
										5) 5	30	142	
										6) 6	00	220	
										7) 6	20	146	
High water at St. 1	11	00	145	20	00	145	(Low water) 20 10 145			5	00	145	

Table 7.3. Maximum Storm Surge (II).

Dike Tide Typhoon Course	Open			Closed			Open			Open		
	Occurrence of high water			(TAR)			High water			High water		
							Ise Bay			Ise Bay		
							5609			5609		
St. No.	h	m	cm	h	m	cm	h	m	cm	h	m	cm
1	0	00	145	0	00	145	5	00	91	5	00	91
2	0	00	153	0	00	146	6	40	75	5	00	95
3	0	20	161	0	10	148	6	40	89	5	00	126
4 (Ext.)	0	30	160	0	00	145	6	40	94	5	00	132
5	10)	1	00	185	2	10	6	20	113	7	40	39
6		1	00	200	2	30	6	00	163	6	40	75
7		1	10	210	2	40	6	00	169	6	30	87
8		1	00	205	3	00	5	40	172	6	20	30
9	11)	1	00	222	3	00	5	40	188	5	00	66
10		1	20	243	3	40	4	40	263	5	20	166
11	12)	1	10	243	3	50	4	40	325	5	20	203
12	13)	1	20	245	3	40	4	40	241	4	40	112
13		1	20	256	3	50	4	00	280	{2 40		149
14	14)	1	30	238	3	30	5	40	134	{7 40		-109
15		1	00	232	3	10	6	20	138	2	00	36
										{1 00		49
										{5 40		-127
16		1	20	233	3	20	6	00	134	7	00	26
17	15)	1	00	197	3	40	6	00	124	7	20	94
4 (Int.)					2	00				{2 00		-35
										{8 00		36
Observation	10)	0	02	180								
	11)	0	12	220								
	12)	0	18	230								
	13)	0	29	240								
	14)	0	11	230								
	15)	0	10	200								
High water at St. 1		0	00	145	0	00	5	00	145	2	20	145

7.9 The Results

In Technical Report of the Japan Meteorological Agency No. 28,⁴⁾ the results of WAR, TAR and SAR are shown in detail. Here the authors only show their main results. The maximum storm surges or tides are shown in Table 7.3. First this table shows in the tidal computations that there exist almost one-hour time difference between computation and observation in the the occurrence of high tide near the head of the bay and that in the closed bay the tidal phenomena almost vanish. Fig. 7.6 shows surges at Miiike in the 1927 typhoon which passed through the bay in the spring high tide. Fig. 7.7 shows

surges at the various stations in the 5609 typhoon, when we can get many tidal records. This typhoon also passed through the bay in the high water. In this case we notice that, at Nameishi and Beniya where the bottom dries up in the low water, the computed surges are fairly smaller than the observed ones. Fig. 7.8 shows surges in the 1942' typhoon which passed through the bay in the spring low water. In this case we computed the surges in the both low and high water. According to the Table 7.3, the computed surges in the low water are greater than those in the high water except at such stations as the bottom dry up in the low water. In the low water we can also say the computed surges fairly exceed the observed ones.

Fig. 7.9 shows the comparison between the surges in the closed bay and in the open bay. Both are computed in the high water. In Fig. 7.10~7.11, we can see the distributions of surges and current velocity in the case of 5609 Typhoon, WAR and SAR, where 6 hour almost corresponds to the occurrence of max. surges and the standing time of current. 3 and 9 hour corresponds to the occurrence of max. flood and ebb.

7.10 Remarks

The following problems yet remains to be studied.

- (a) The method for expression of pressure and wind in the typhoon

As we know from Fig. 7.4, 7.5 the computed weather elements are not enough to coincide with the observation quantitatively.

- (b) the friction of wind and bottom

This is one of the most difficult problem in our computation. In fact, at the head of bay, the computed high water occurs almost one hour later than the observed, and in such the case as the direction of wind is opposite to that of current, which occurs when the typhoon passes through this bay in the low water, the computed surges fairly exceeds the observation as we have stated.

- (c) the non-linear terms

Though very important in this case, they are neglected due to the technical difficulties in computation.

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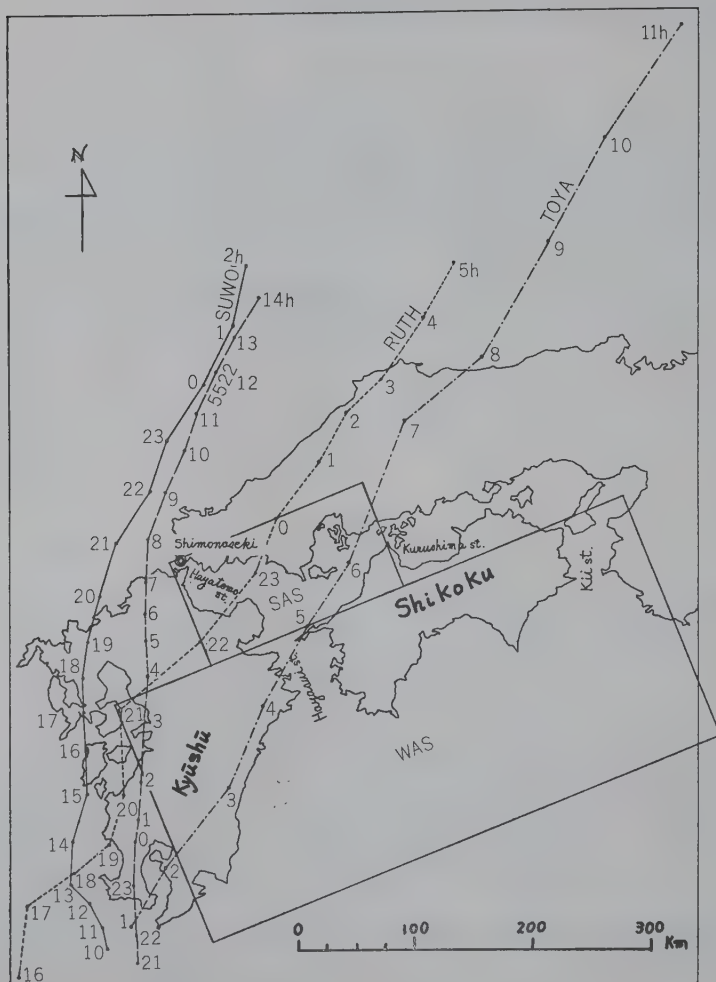


Fig. 6.1. Computed areas and typhoon courses in the case of Western Part of Inland Sea.

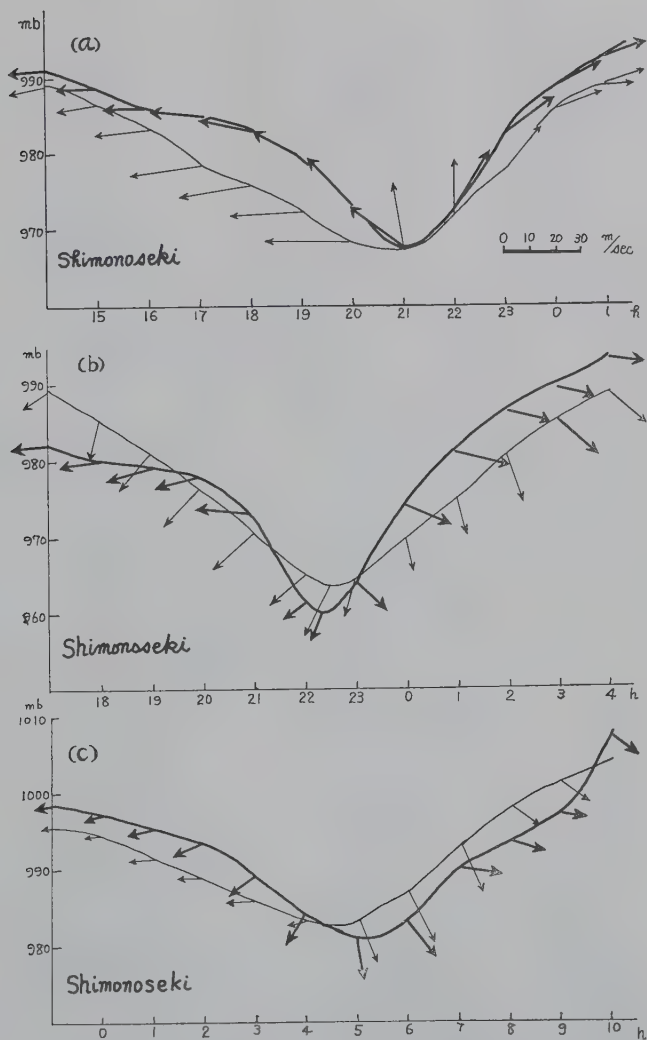


Fig. 6.2. Variations of pressure and wind at Shimonoseki.
(broad line, observed; slim line, computed)
(a) Suwo typhoon, (b) Ruth typhoon, (c) Toya typhoon

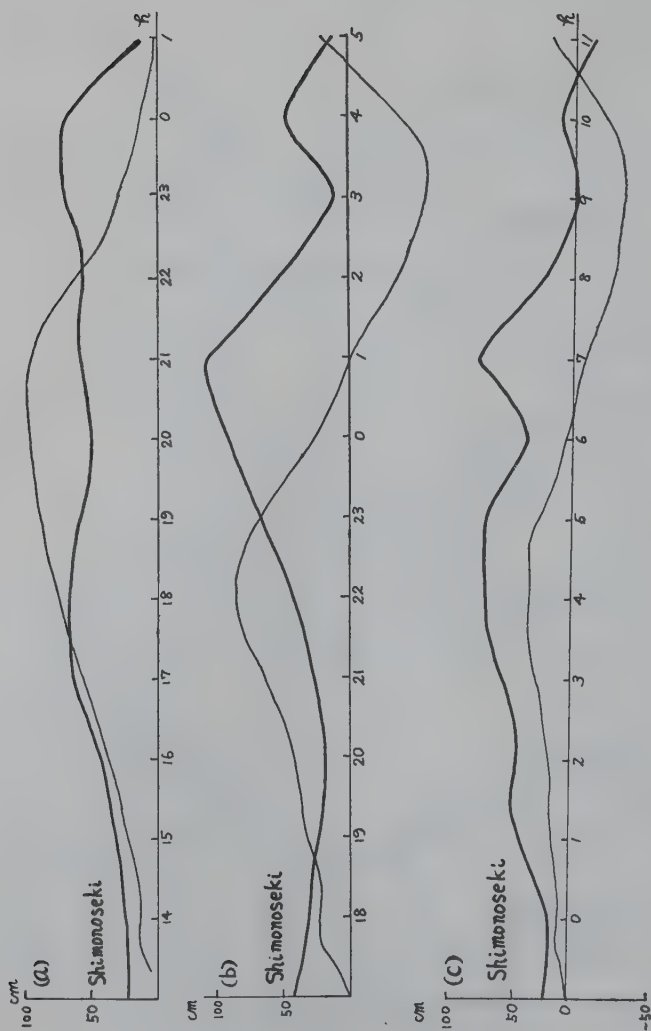


Fig. 6.3. Variations of surges at Shimonoseki.
(broad line, observed; slim line, computed)
(a) Suwo typhoon, (b) Ruth typhoon, (c) Toya typhoon

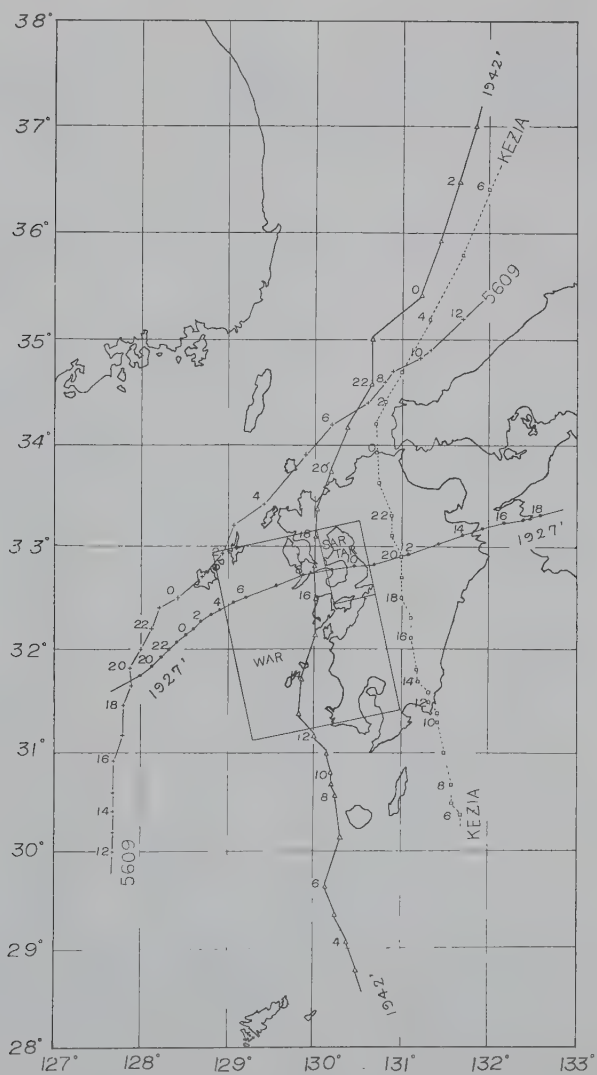


Fig. 7.1. The concerning areas and typhoon courses in the computation for Ariake Bay.

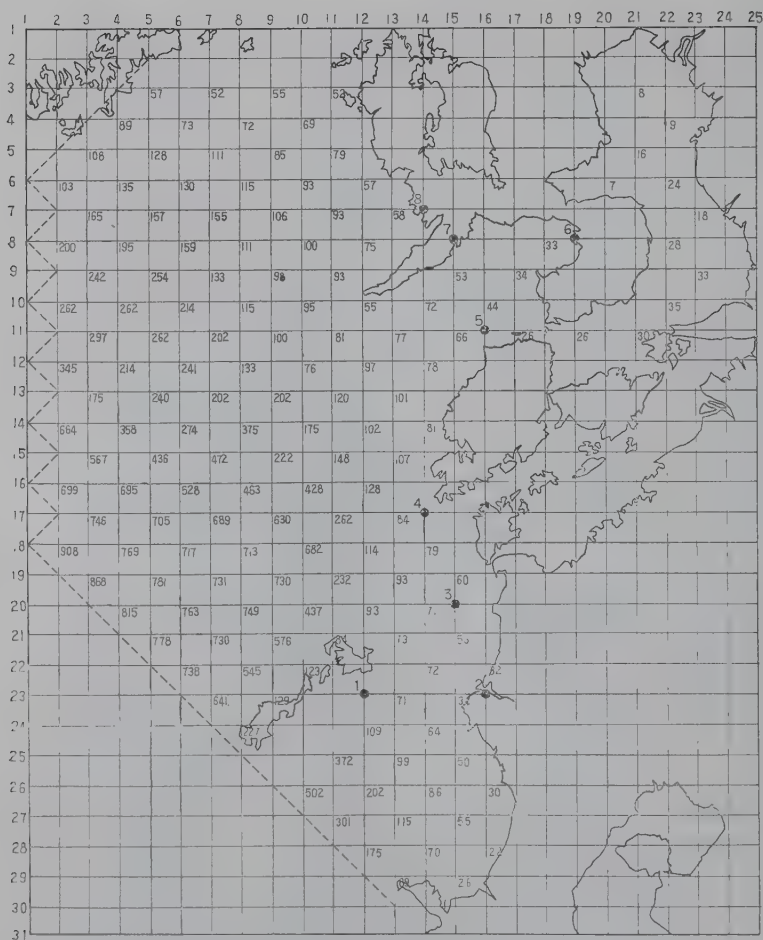


Fig. 7.2. The arrangement of mesh points and their depths (m) in WAR.

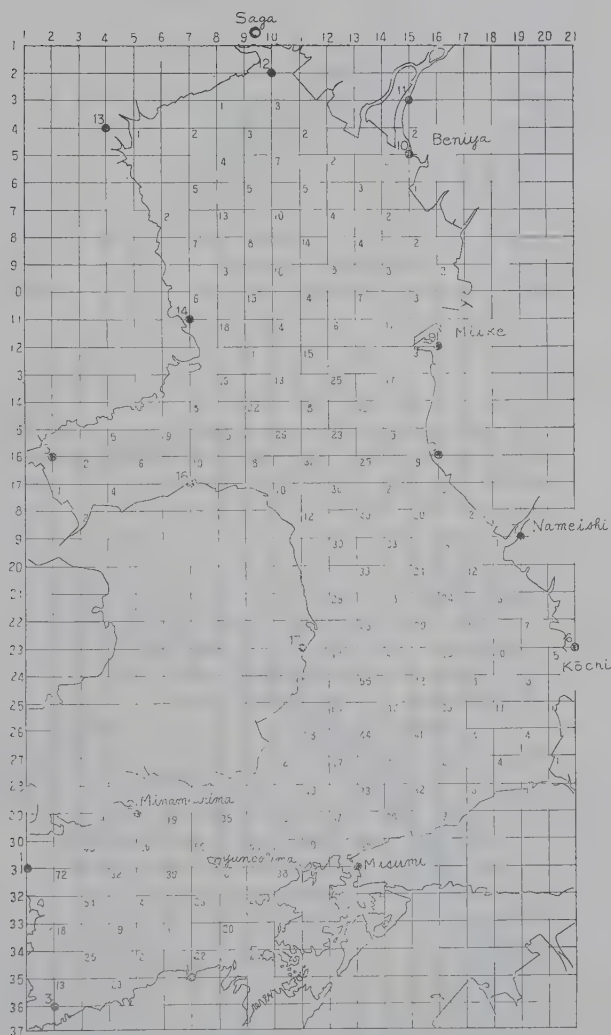


Fig. 7.3. The arrangement of mesh points and their depths (m) in TAR and SAR.

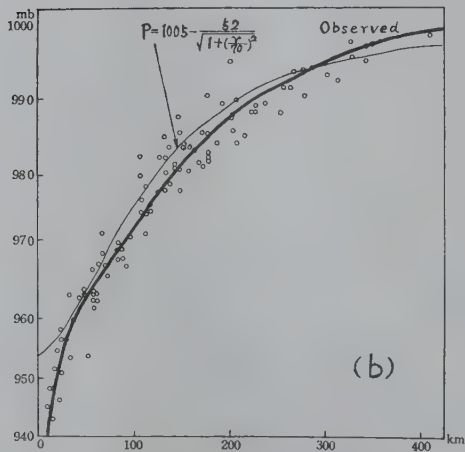
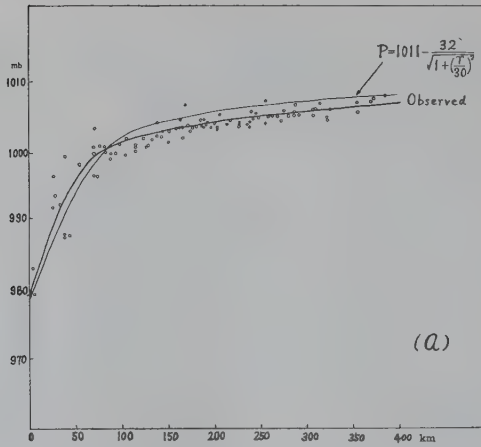


Fig. 7.4. The distribution of air pressure in the typhoon.
 (broad line, observed; slim line, computed)
 (a) 1927's typhoon, (b) 1942's typhoon

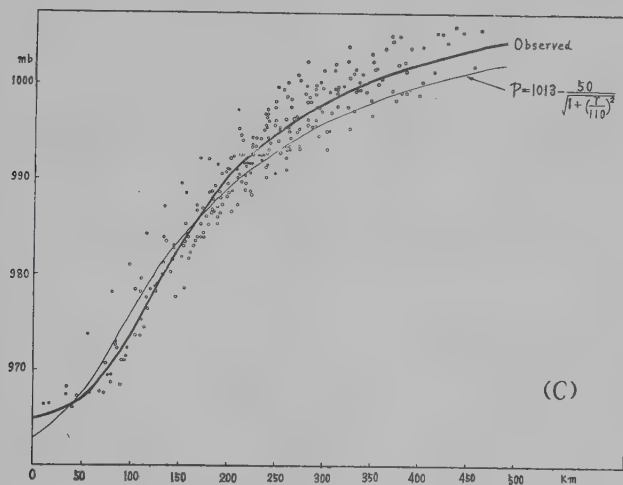


Fig. 7.4. (Continued) (c) 5609 typhoon

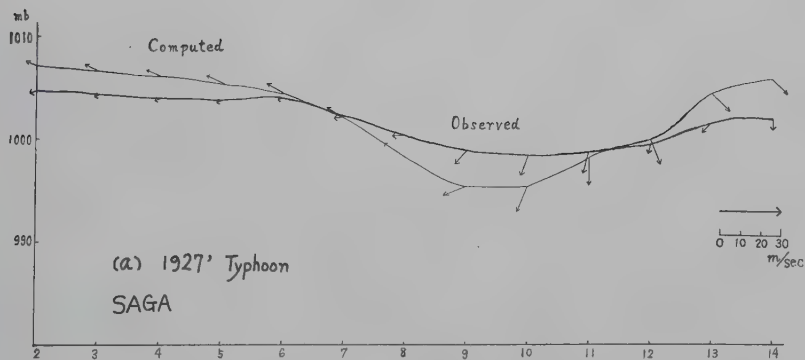


Fig. 7.5. The variation of air pressure and wind at Saga.

(broad line, observed; slim line, computed)

(a) 1927's typhoon

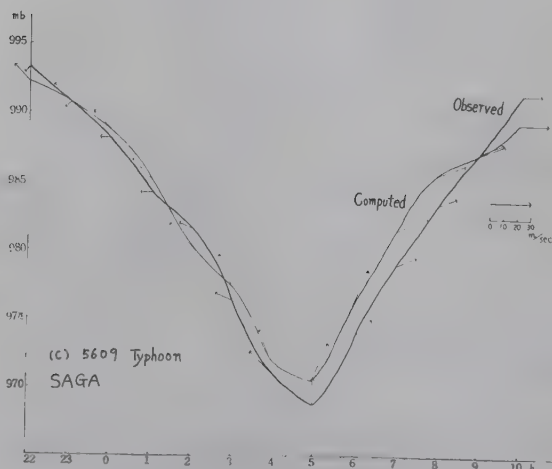
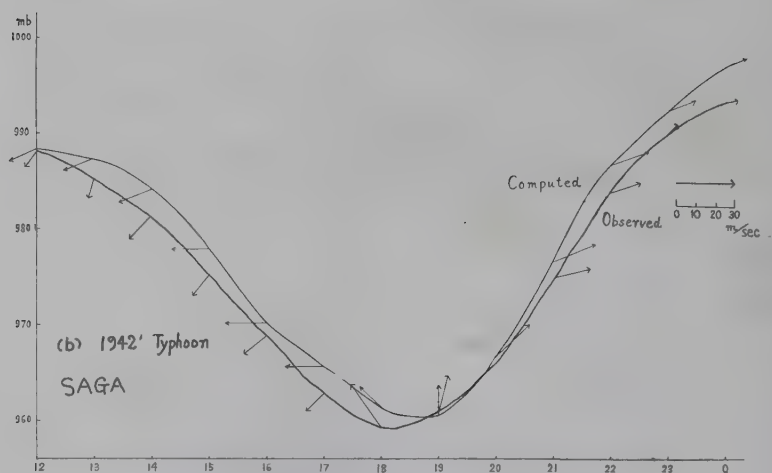


Fig. 7.5. (Continued). (b) 1942's typhoon, (c) 5609 typhoon

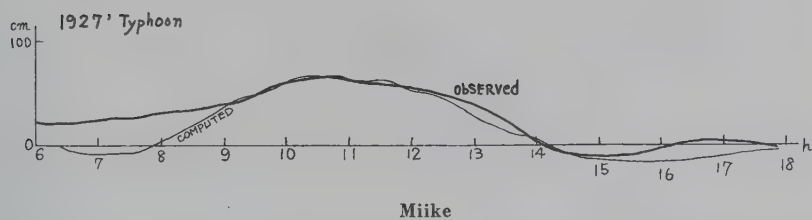


Fig. 7.6. Surges at Miike in the 1927's typhoon.

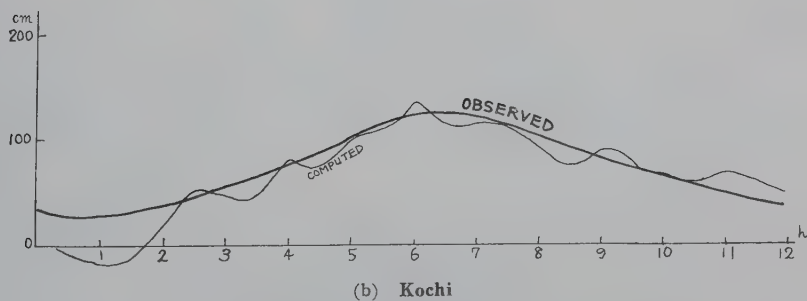
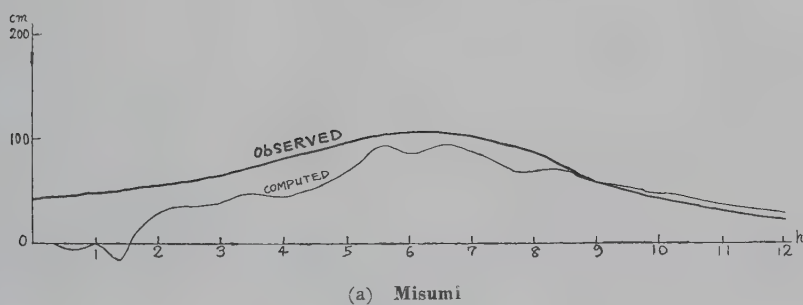
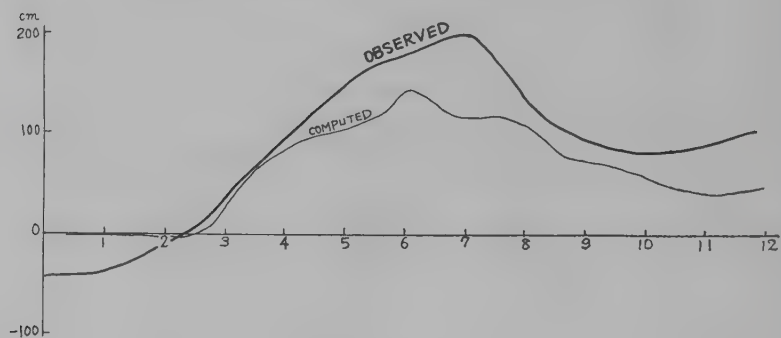
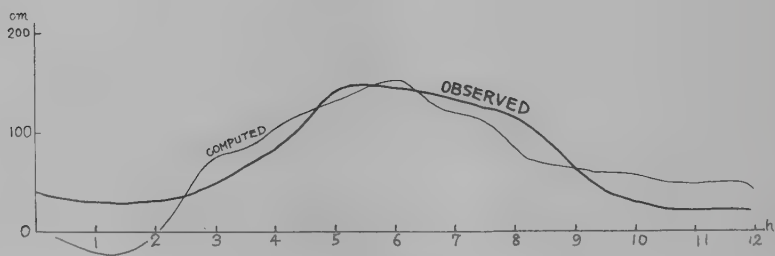


Fig. 7.7. Surges in the 5609 typhoon.

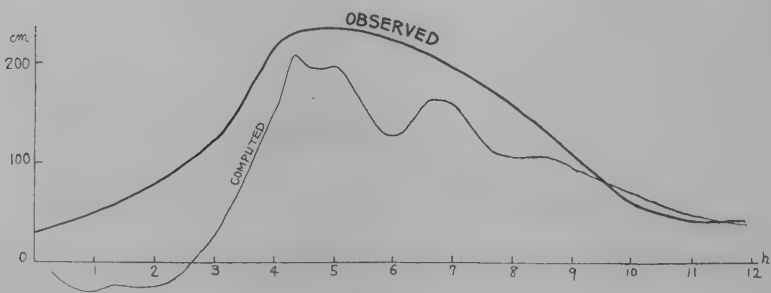
(a) Misumi, (b) Kochi



(c) Nameishi

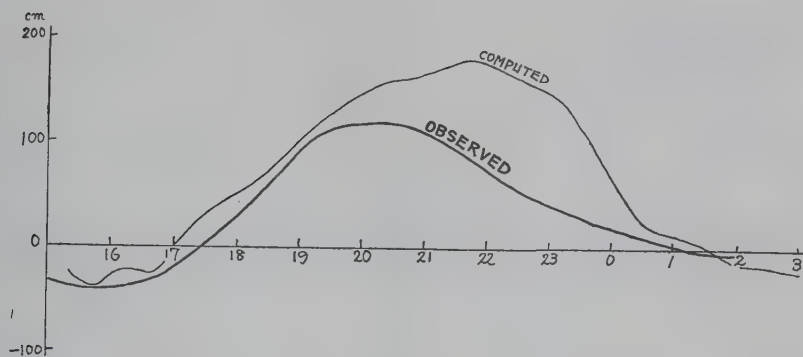


(d) Miike

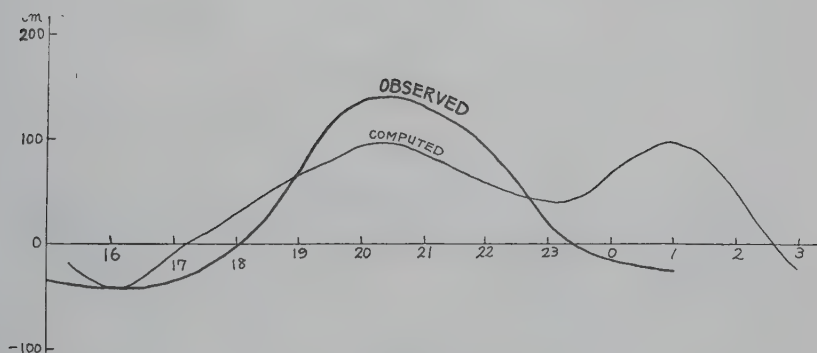


(e) Beniya

Fig. 7.7. (Continued). (c) Nameishi, (d) Miike, (e) Beniya



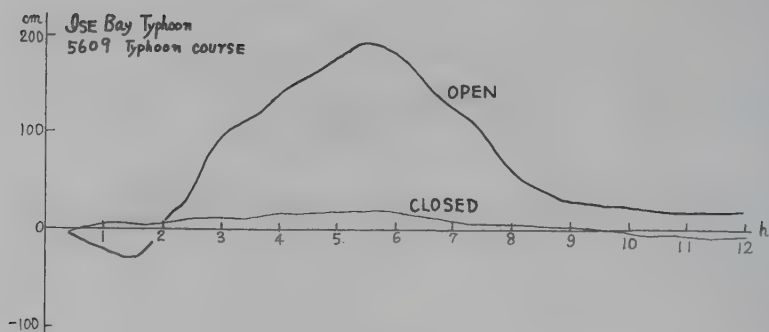
(a) Miike



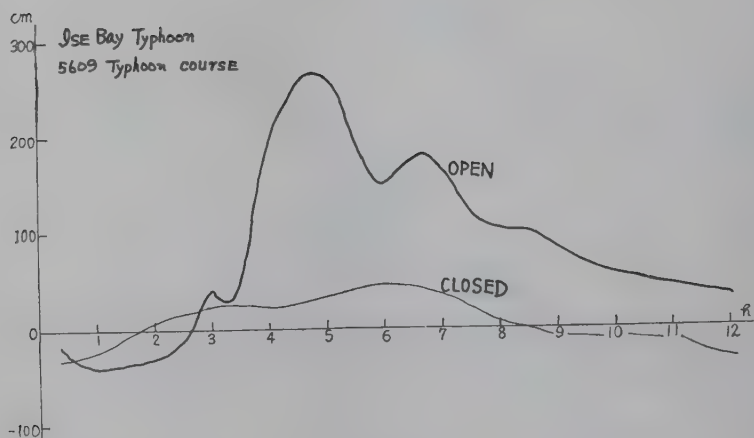
(b) Beniya

Fig. 7.8. Surges in 1942's typhoon.

(a) Miike, (b) Beniya



(a) Miike



(b) Beniya

Fig. 7.9. Comparison of the computed surges of closed bay with those of open bay.

(a) Miike, (b) Beniya

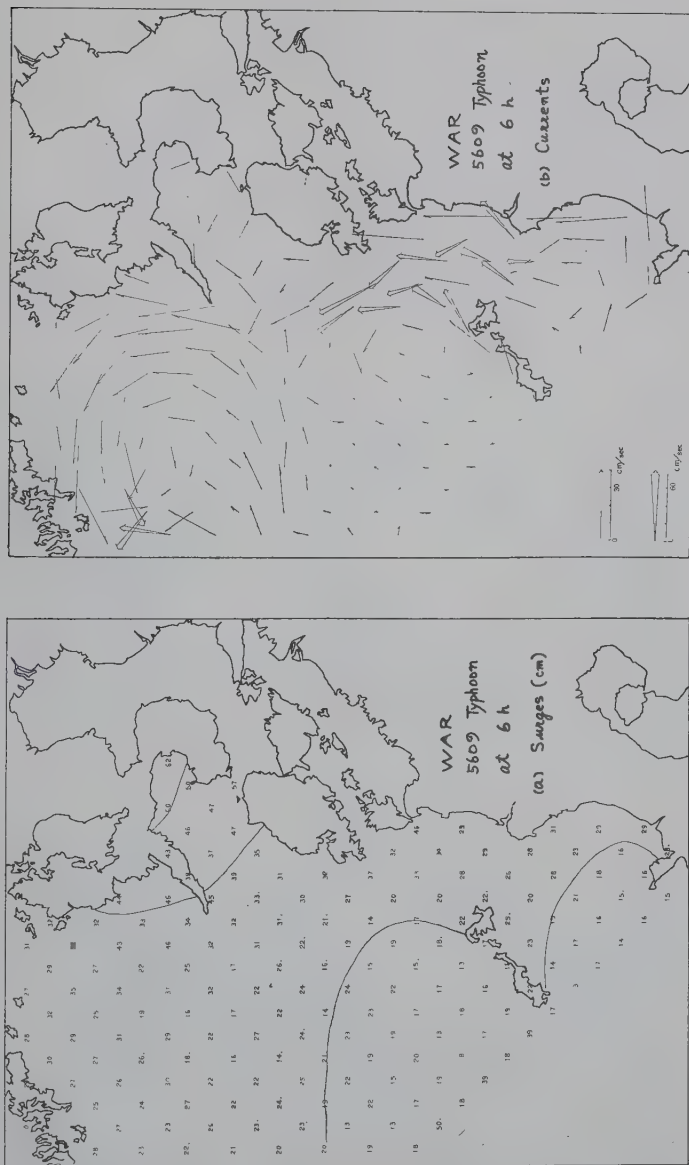


Fig. 7.10. The distribution of surges and current velocity in 5609 typhoon, WAR.

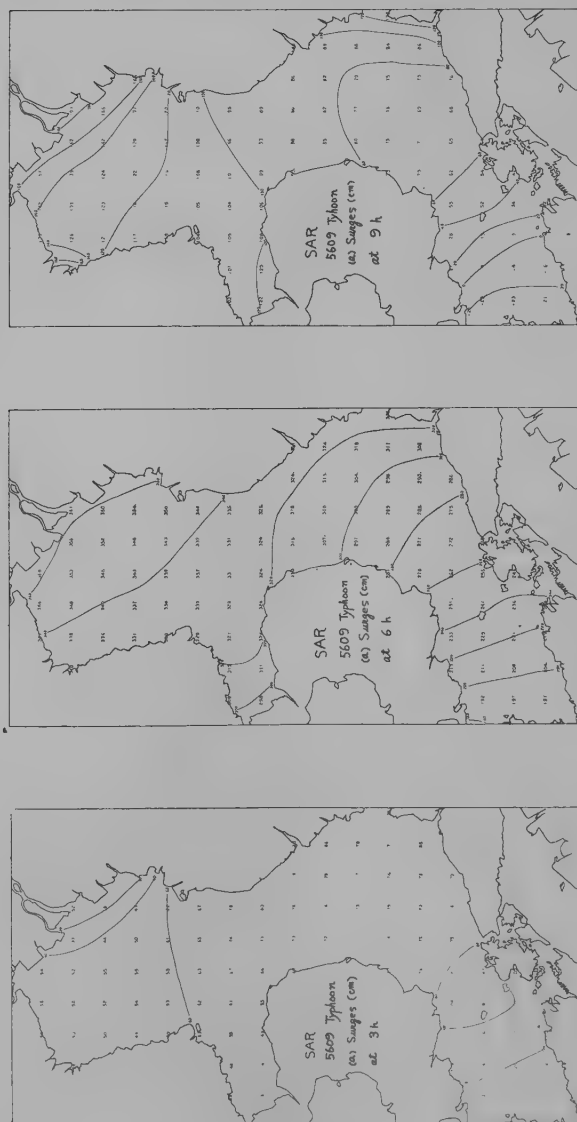


Fig. 7.11 (a). The distribution of surges in 5609 typhoon, SAR.

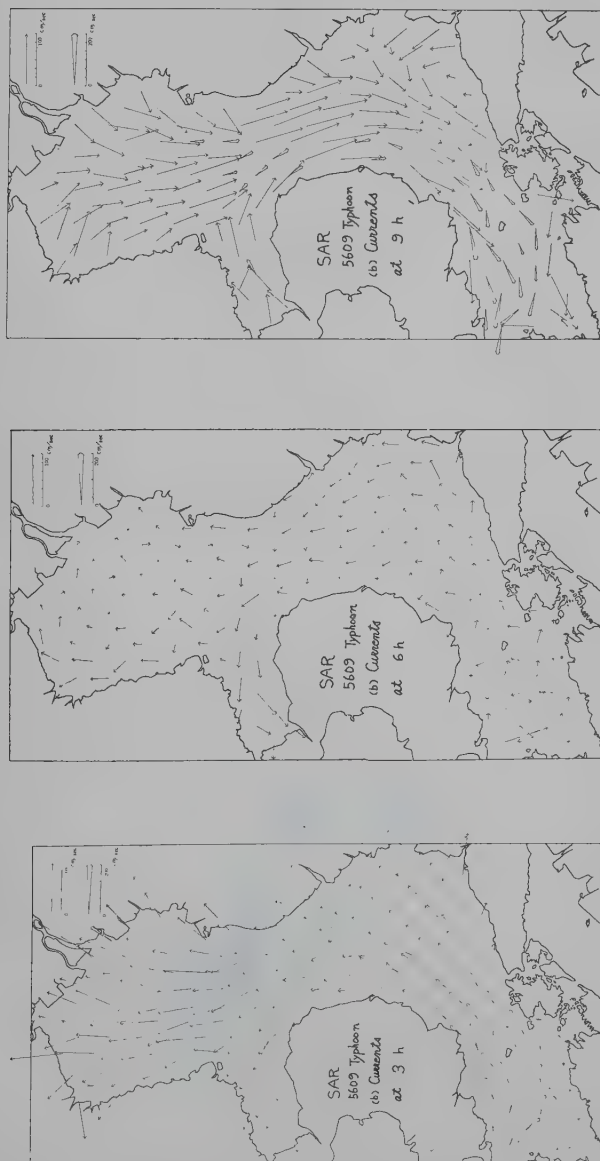


Fig. 7.11 (b). The distribution of current velocity in 5609 typhoon, SAR.

On Chaetognaths Collected in the Japan Trench

1. The Fourth Cruise of the Japanese Expedition of Deep Seas*

By

Masataka KITOU

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Abstract : At the station E2 (Fig. 1) of the Fourth Japanese Deep Seas Expedition, plankton collections were carried out with 130 cm conical net in the five layers, i. e. 0-580 m, 0-1000 m, 0-3000 m, 0-5000 m and 0-7000 m.

Sagitta lyra and *Eukrohnia hamata* are dominant in the present collections. *Sag. lyra* is concentrated upper 580 m depths and rare below 580 m depths. *Eukroh. hamata* is distributed upper 3000 m depths, and it is dominant in both of the 580-1000 m and 1000-3000 m layers. Among three species of bathy-pelagic chaetognaths, occurrence of *Sag. macrocephala* and *Eukroh. fowleri* is confined below 1000 m depths, but *Sag. planctonis* occurred even upper 580 m depths.

1. Introduction

In June of 1961, the Fourth Cruise of the Japanese Expedition of Deep Seas (JEDS-4) was carried out along the latitude of 38°N on board the research vessel Ryofu-Marui of the Japan Meteorological Agency. In the present paper,

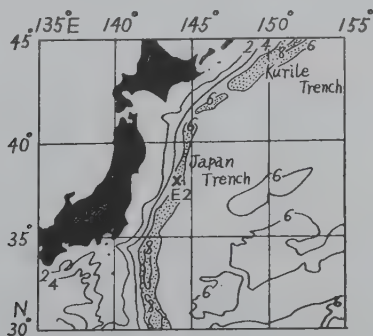


Fig. 1. Station

* JEDS Contribution No 52.

the vertical distribution of chaetognaths at the station E 2 with the depth of 7300 m in the Japan Trench (Fig. 1) will be given.

The net used is so-called "130cm conical net". The net has a mouth ring with 130 cm in diameter and the conical filtering part with 500 cm in side length. The filtering part is consisted of two parts. In the upper 400 cm part coarse nylon cloth is used and in the lower 100 cm part bolting cloth is used. The aperture size of mesh is 3.0 mm and 0.33 mm, respectively. Towing of the net was made vertically in five layers, i. e. 0-580 m, 0-1000 m, 0-3000 m, 0-5000 m and 0-7000 m.

Following thirteen species of chaetognaths were found in these samples.

<i>Sagitta hexaptera</i>	<i>Sag. decipiens</i>
<i>Sag. lyra</i>	<i>Sag. planctonis</i>
<i>Sag. enflata</i>	<i>Sag. macrocephala</i>
<i>Sag. elegans</i>	<i>Krohnitta subtilis</i>
<i>Sag. bedoti</i>	<i>Eukrohnia hamata</i>
<i>Sag. serratodentata</i>	<i>Eukroh. fowleri</i>
<i>pseudoserratodentata</i>	
<i>Sag. minima</i>	

2. Distribution

Detailed quantitative result is shown in Table 1. The present station is located in the transition area between the warm Kuroshio and the cold Oyashio waters, where such representative warm water species as *Sag. enflata*, *Sag. hexaptera*, *Sag. ser. pseudoserratodentata* and *Krohnitta subtilis* and such cold water species as *Sag. elegans* occurred together, though few in number, especially rather rare in most of the warm water species. *Sag. bedoti* was found in every collection. This is the important species characterizing the shallower water of the transition area as "bedoti-water". *Sag. decipiens*, the mesoplanktonic species in the warm oceanic waters, was rare. It is considered that the transition area agrees with the northern distributional boundary of *Sag. decipiens*, because this animal was not collected in the Kurile-Kamchatka Trench (TCHINDONOVA, 1955).

Sag. planctonis, *Sag. macrocephala* and *Eukroh. fowleri* are representative bathy-pelagic species. *Sag. planctonis* occurred in every collection, however the body length was different according to the depth. That is, in the 0-580 m layer, specimens were less than 22 mm, while in both of the 0-3000 m and the 0-5000 m

M. Kitou: On Chaetognats Collected in the Japan Trench

Table 1. Individual number of chaetognaths collected with "130-cm conical net" at station E2 (JEDS-4)

Towing depth (m)	0-580	0-1000	0-3000	0-5000	0-7000
<i>Sagitta enflata</i>	—	—	—	—	1
<i>Sagitta hexaptera</i>	1	1	6	1	—
<i>Sagitta lyra</i>	197	73	217	187	95
<i>Sagitta elegans</i>	3	3	6	10	8
<i>Sagitta bedoti</i>	21	12	19	3	2
<i>Sagitta serratodentata pseudoserratodentata</i>	—	—	—	—	1
<i>Sagitta minima</i>	1	—	2	3	—
<i>Sagitta decipiens</i>	—	1	—	—	—
<i>Sagitta planctonis</i>	14	3	30	12	2
<i>Sagitta macrocephala</i>	—	—	5	7	1
<i>Krohnitta subtilis</i>	—	1	2	—	—
<i>Eukrohnia hamata</i>	96	188	637	445	509
<i>Eukrohnia fowleri</i>	—	—	54	17	21
Damaged individuals and juv.	40	28	33	65	16
Total	373	310	1012	750	656

layers, half of them was more than 30 mm, and the maximum reached to 37 mm. *Sag. macrocephala* and *Eukroh. fowleri* were not found in the upper 1000 m depths. The former is very few in number, but the latter is relatively abundant.

It is noticeable fact that chaetognath fauna is represented by two species of *Sag. lyra* and *Eukroh. hamata* in this station. *Sag. lyra* is considered to be distributed mainly upper 580 m depths, because the number of specimens in the four layers is equal to or smaller than it in the 0-580 m layer. As for the body length of *Sag. lyra*, the greater part of specimens is included in the range from 20 mm to 35 mm. The maximum and the minimum are 50 mm and 11 mm, respectively. The larger specimens than 36 mm are very few and are confined below 1000 m depths.

BIERI (1959) concluded as a result of the many expeditions around the Pacific that it was difficult to draw any conclusion on the distribution of *Sag. lyra*, because the distribution was so patchy. However, HIDA (1957) stated that *Sag. lyra* increased in the transition area of the Hawaiian Islands. Also, TOKIOKA (1959) stated that this animal increased in the transition area of the eastern Pacific. Those phenomenon are expected in the transition area of the western

North Pacific, too. In order to clear up the distribution of *Sag. lyra*, it is necessary that collections must be made from deep layers enough with large nets.

The individual number of *Eukroh. hamata* is the largest in the sample collected in the 0-3000 m layer, which seems to indicate *Eukroh. hamata* being distributed upper 3000 m depths. Thus, the numbers of individual in the 0-580 m, 580-1000 m and 1000-3000 m layer were calculated to 0.13, 0.16 and 0.17 per 1 m³ of sea water. The maximum and the minimum sizes of *Eukroh. hamata* are 28 mm and 8 mm, respectively. In the 0-580 m layer, *Eukroh. hamata* is small, being less than 18 mm, and the individuals smaller than 15 mm occupied 65% to total number. While, in other layers the individuals larger than 15 mm occupied about 70%. In the Kurile-Kamchatka Trench, *Eukroh. hamata* has been distributed to the 2000 m depths and has been abundant upper 500 m depths. According to Tchindonova's data (1959), the numbers of individual in the 0-500 m layer were calculated to about 2.5 and 4.0 per 1 m³ of sea water. It is obvious that the production of *Eukroh. hamata* in the transition area is conspicuously reduced in comparison with it in the Subarctic Waters.

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